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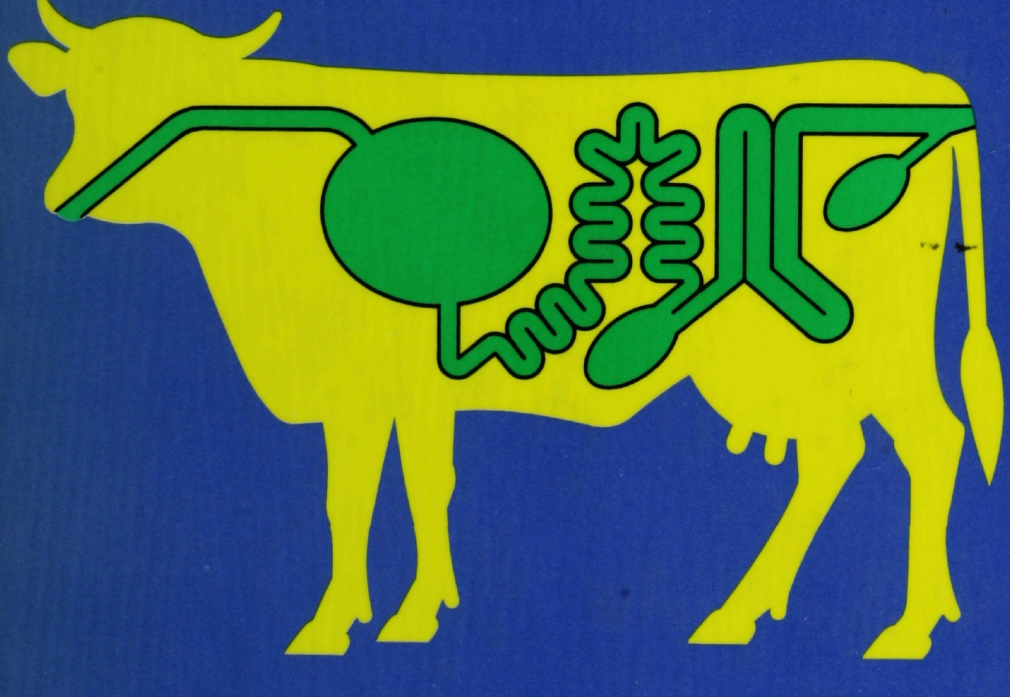
H. W. Ockerman,
C. L. Hansen

Animal By-Product Processing



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Animal By-Product Processing

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Dedicated to

Frances J. Ockerman
and
Joyce D. Hansen

Preface

Animal by-product utilization has been a remarkable economic and public health phenomenon, but, in spite of this success, published information in this area has been extremely limited. The most widely quoted book published in the U.S. has a 1927 copyright date and articles in the scientific literature are also extremely limited in number. Fortunately some of the trade association and industry personnel were extremely helpful in sharing information with the authors on this subject matter (see references listed). Dr Vern R. Cahill of the Ohio State University and Dr Divakaran of the Oceanic Institute, Waimanald, Hawaii were also helpful consultants and proof-readers. The increased economic squeeze on animal processors, increased emphasis on pollution, the energy crisis and competition from man-made items will challenge the by-products industry into the forseeable future, but with the track record it has already established, it is reasonable to expect that new innovation will continue. Any industry that turns waste into valuable products ought to be applauded. The authors would appreciate additional information about this varied industry for their files and in case a revision of this text is ever produced.

Herbert Ockerman
Conly Hansen

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Introduction to animal by-product processing

INTRODUCTION

Animals are grown and slaughtered to provide nutritious meat for humans, and without this utilization, few of what we consider 'meat' animals would be allowed to exist except as examples of species in zoos. As the economic stature of a country or race increases there is often a shift in its diet and nutrition to include a greater percentage of tasty, well-balanced protein from animal sources. With this consumption of a well-balanced protein from meat, the people's size (particularly height) usually tends to increase.

With all of the natural advantages of animal food products, there still remains a great quantity, often in excess of 50%, of animal by-products of rather unusual physical and chemical characteristics which are not part of the normally consumed steaks and roasts. The efficient utilization of these edible and inedible products is the subject of this book.

The quantity of animal by-products available can be estimated by subtracting the dressing percentage (see Table 1.1) from 100. This large quantity of material can then be increased by the quantity of fat and bone that traditionally remains with the carcass at the slaughter stage; therefore, it is obvious that tremendous tonnage of this material is involved.

The economics of the world's meat industry demand that animal by-products be utilized so that the livestock industry can stay economically competitive with vegetable protein sources. If animal by-products are not effectively utilized, of course, a valuable source of potential revenue is lost, and the added and increasing cost of disposal of these products is incurred by the industry. Today the cost of the live animal often exceeds the selling price of its carcass; therefore, the value of the by-products must pay the expense of slaughter and generate the profit for the meat-slaughtering operation.

In addition to the economics involved, the meat industry has the obligation to eliminate waste by salvaging as much of the animal as possible, since this is a valuable natural resource and responsible people are expected to be effective stewards of the resources placed at their disposal. Since much of the world's vegetation can only be

Table 1.1 — Dressing percentage (carcass weight/live weight ×100), when subtracted from 100%, will give an estimate of the quantity of by-products

U.S. grades	Dressing percentages	
	Range	Average
Cattle		
Prime	62–67	64
Choice	59–65	62
Good	58–62	60
Standard	55–60	57
Commercial	54–62	57
Utility	49–57	53
Cutter	45–54	49
Canner	40–48	45
Calves and veal (hide off)		
Prime	59–65	62
Choice	56–60	58
Good	52–57	55
Standard	47–54	51
Utility	40–48	46
Lambs (wooled)		
Prime	49–55	52
Choice	47–52	50
Good	45–49	47
Utility	43–47	45
Cull	40–45	42
Sheep (excludes yearlings)		
Choice	49–54	52
Good	47–52	49
Utility	44–48	46
Cull	40–46	43
Barrow and gilt (ham facings, leaf fat, kidneys and head removed)		
U.S. No. 1	68–72	70
U.S. No. 2	69–73	71
U.S. No. 3	70–74	72
U.S. No. 4	71–75	73
Utility	67–71	69
Poultry		
Chicken, broilers	—	70
Chicken, capon	—	68
Turkey, broiler	—	77
Duck, Peking	—	58
Pheasant	—	78

USDA Market News (1973), Mountney (1966).

harvested by animals and it takes energy to organize these chemical by-product structures, it would behoove mankind to utilize these by-products, where possible, in the organized form and not allow them to be converted to a lower energy state.

Non-utilization of animal by-products would, of course, create a major aesthetic and catastrophic public-health problem. The effective utilization of animal by-products and water- and sewage-treatment plants have probably been the major influences in upgrading public health in the last century.

The modern livestock industry has been an effective utilizer of by-products and it has often been stated that 'all of the pig is used except the squeal and the curl in the tail'. But in spite of this a great deal more can be done, since more than 2% of the carcass (more than the shrinkage) is often unaccounted for and is lost to the server. Also, to achieve utilization, many of the products are down-graded in value.

A flow-chart showing the interrelationships between land, water, animals and animal by-products is illustrated in Fig. 1.1. Another flow-chart showing a few examples of the tremendous variety of animal by-products that may be involved can be found in Fig. 1.2.

Some products such as hides are easy to classify as 'animal by-products', and products such as steaks can easily be excluded from such a classification. Other products, however, such as lard or liver, are more difficult to categorize. The U.S. meat industry considers everything produced by or from the animal, except dressed meat, as a by-product (offal). Therefore, animal by-products in the U.S. fall into two categories and the divisions are 'edible' and 'inedible'.

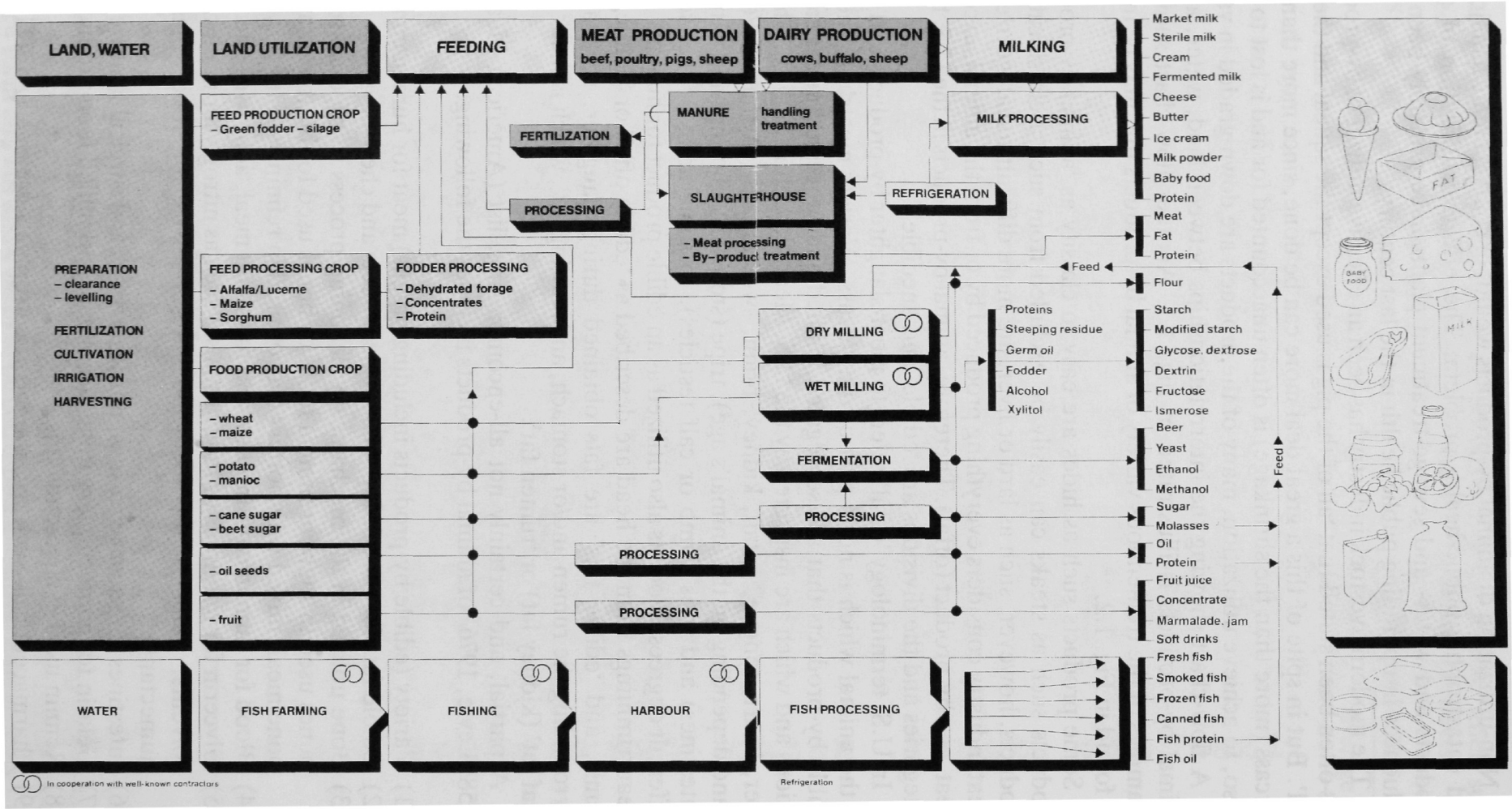
In U.S. terminology 'offal' refers to meat-slaughter by-products and includes all of the animal which is not a part of the carcass. 'Variety meats' are the wholesale edible by-products that are segregated, chilled and processed under sanitary conditions and which are inspected by the U.S. Meat Inspection Service. These include liver, heart, tongue, oxtail, kidney, brain, sweetbreads (thymus and/or pancreas gland depending on the animal's age), tripe (stomach), chitlings and natural casings (intestines) and fries (lamb or calf testicles). In some areas of the world and to different degrees, blood is also utilized as an edible product for humans. In the U.S. meat trimmings from the head are described as 'edible offal' or 'edible by-product items', and 'edible fats' are fats obtained during slaughter, such as 'caul fat' surrounding the rumen and/or stomach, and 'cutting fat', which is 'back fat' or pork 'leaf fat' (kidney fat) or 'rumen fat'.

A partial, and certainly not all-encompassing, list (American Meat Institute, 1958; Levie, 1976) of animal by-products includes the following:

(1) Variety (edible by-products including organs) meat for human consumption.
(2) Edible fats for shortening, margarine, sweets and chewing gum.
(3) Bone utilized in the mechanically deboning process to produce soft tissue or bones used in soup for human food, or bones used for buttons, knife handles, bone meal, mixed with pottery clay or used in refining sugar.
(4) Blood for human consumption and for blood meal, adhesives and fertilizer.
(5) Glycerin for hundreds of industrial uses such as nitroglycerin, ointment bases, solvents, vehicles for medicine, preservatives for food, plasticizers or humectants.
(6) Intestines for sausage casings, musical strings and surgical ligatures.
(7) Gelatin for confectionery items, ice-cream and jellied food products.
(8) Rennin used in cheese making.
(9) Pharmaceuticals such as adrenocorticotrophic hormone (ACTH), albumin,

From virgin land to green pastures and food products

planning, integration, modern production methods, know-how of local conditions, management, packaging, distribution



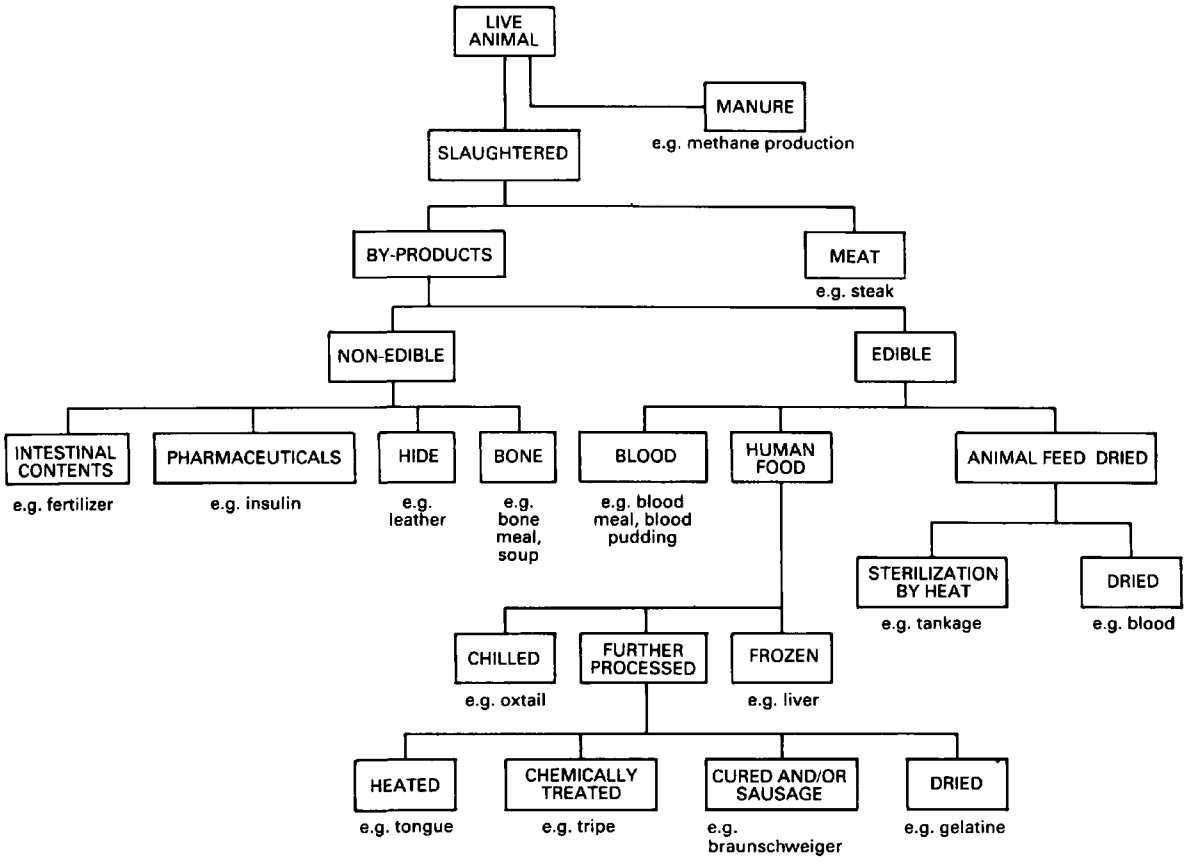


Fig. 1.2 -- Flow diagram of a few of the meat industry by-products.

bilirubin, epinephrine, insulin, liver extract, pepsin, pituitrin, testosterone, thromboplastin, thymocrescin and thyroxin.

(10) Organ parts for implantation into humans, such as heart valves, skin, and bones and, experimentally, even whole hearts.
(11) Livestock feed (usually high in protein or fat or minerals) manufactured from by-products.
(12) Pet food and feed for aquatic farming.
(13) Hides and skins for use as fur, leather or leather goods.
(14) Wool for clothing and furniture, and lanolin extraction.
(15) Inedible fats used for many industrial products, such as tyres, lubricants, insecticides and germicides.
(16) Hair for brushes, felt, rugs, upholstery, plaster binding, insulation and athletic equipment.
(17) Feathers for insulation, pillows, sporting goods, and animal feed.
(18) Glue used in carpentry, for sizing, sandpaper, emery cloth, and making boxes and plywood.
(19) Neat's foot oil used in the leather industry and as a lubricant.
(20) Fertilizer applied to soil is manufactured from by-products.
(21) Animal manure used as fertilizer, animal feed and/or methane production.

The division of cattle (Fig. 1.3) and sheep (Fig. 1.4) into various product categories is illustrated in pie charts.

In English commercial slaughterhouse practice (Garrard, 1972) the offal is divided into red (head, heart, liver, lungs, melt (spleen), sweetbreads, tail, thick skirt (diaphragm) and tongue) and white (fats, manyplies (third stomach), set of guts and bladder, set of tripe (weasand, first, second and fourth stomach) and rectum) and four feet and trimmings. Blood, hides and pharmaceuticals are usually considered as a separate category. The English Food Standards Committee (Food Standards Committee of the Ministry of Agriculture, Fisheries and Food, 1972) separated offal into two categories. List A — items which may be used in cooked or uncooked products from mammalian species — contains tissues such as diaphragm (skirt, cattle only), head meat (ox cheek, cattle only; bath chip, pig only), heart, kidney, liver, pancreas (sweetbreads), tail meat (oxtail, skinned, cattle only), thymus (sweetbreads, cattle and sheep only), and tongue and avian parts such as heart and liver (giblets, when gizzard and neck of list B are included). List B — items which may not be used in uncooked products — contains portions of the mammalian species such as blood, blood plasma, brains, feet (cow heel, cattle only; sheep trotters, sheep only; pig trotters, pig only), large intestines (chitlings, pigs only), small intestines, lungs (lites), oesophagus meat, rectum, spinal cord, stomach (non-ruminant), first stomach (tripe, after cooking), second stomach (tripe, after cooking), fourth stomach, testicles (lamb fries, lamb only), udder and parts of avian species such as gizzard (giblets, when the heart and liver are also included) and neck.

The percentages of by-products from different species, divided into major categories by different countries may be found in Table 1.2.

Several requirements (Clemen, 1927) are necessary for animal by-products to be effectively utilized and these are:

(1) There must be a practical commercial process for converting the animal by-product into a usable commodity.
(2) There must be an actual or potential market for the commodity that has been produced.
(3) There must be a large enough volume of economically priced animal by-product material in one location for processing.
(4) There must be some method of storing the perishable product before processing and to store the manufactured product after processing.
(5) There is often a critical need for highly technically trained operatives.

Getting all of these requirements together at one time in one place is not always an easy task. For reasons including these, animal by-products are often underutilized.

HISTORY

Archaeological evidence suggests that some animal by-product utilization was well established prior to recorded history. Use of organ tissue for food, utilization of animal skins for clothing and housing, making of tools from bones, use of dried manure as fuel, use of intestinal parts for food containers and utilization of fish for fertilizer in planted crops are just a few known examples.

The books *Rendering, The Invisible Industry* (Burnham, 1978) and *Darling-Delaware Centenary* (Dainty, 1981) describe the early recorded history of animal by-

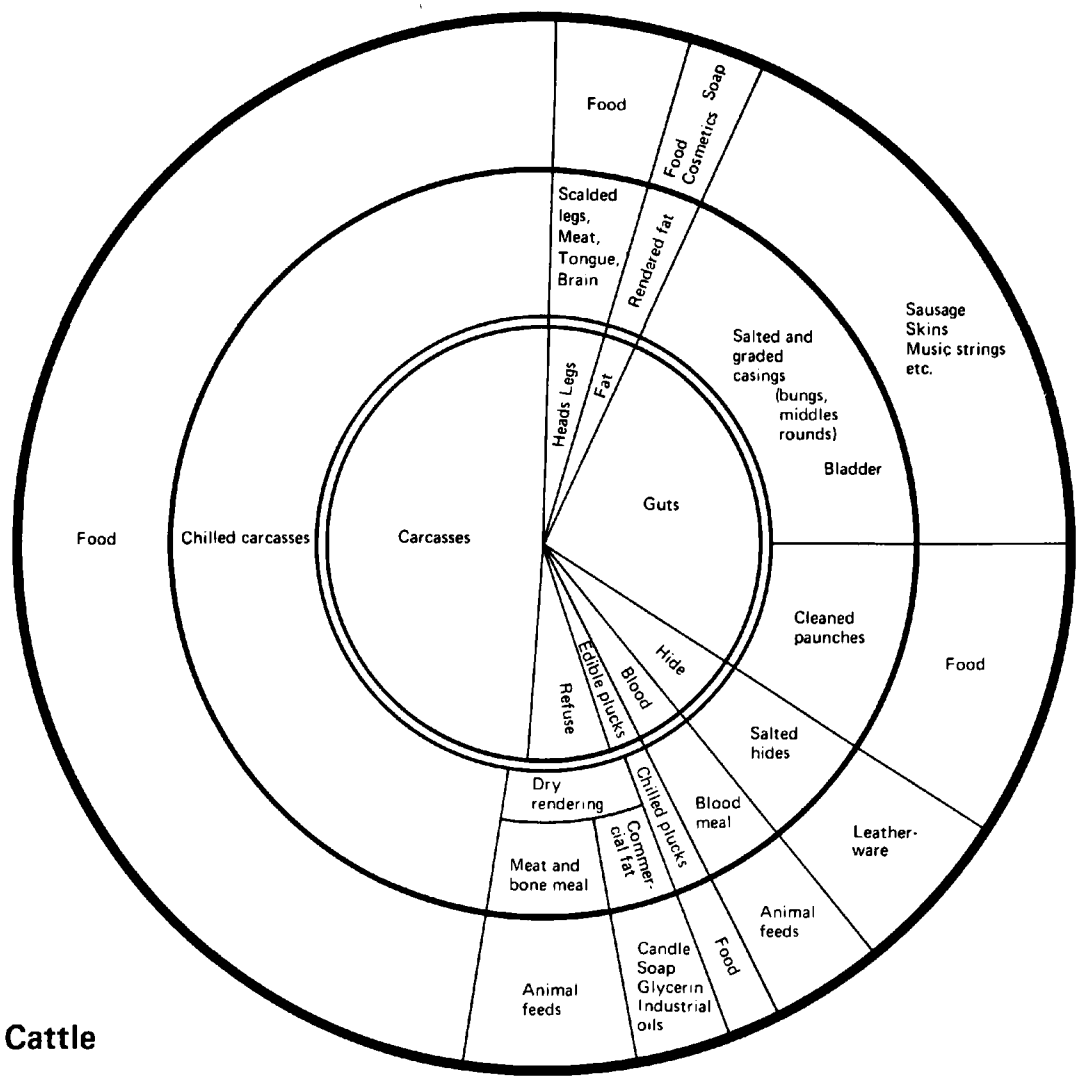


Fig. 1.3 — Division of cattle into various product categories. From Filstrup (1976).

product utilization and a summary of some of the milestones found in these references are as follows.

Plinius Secundus (Pliny the Elder), a Roman scholar in the first century A.D., recorded man's first written record of animal fat utilization. He described a cleaning compound (soap) made from goat's tallow and wood ashes, but it was uncertain if the Romans got the idea for making soap from the wandering Bedouins, or from the Celts who are known to have made 'saipo'. Later descriptions of soap making and 'saponarius' can be found in the works of a Greek physician (A.D. 130–200), the authors Theodorus Priscianus (A.D. 385) and Jabir Ibn Hayyan (approximately A.D. 800). It was not until 1823, however, that the French chemist Chevreul described saponification as the process of splitting fat (triglycerides) with an alkali into an alkali salt of a fatty acid (soap) and glycerin.

It is unclear historically whether an open saucer containing oil and a fibrous wick (later developed into a lamp) or a candle with a wick encased in solid fat (usually cattle and/or sheep fat) was developed first. It is recorded that candle-dipping goes

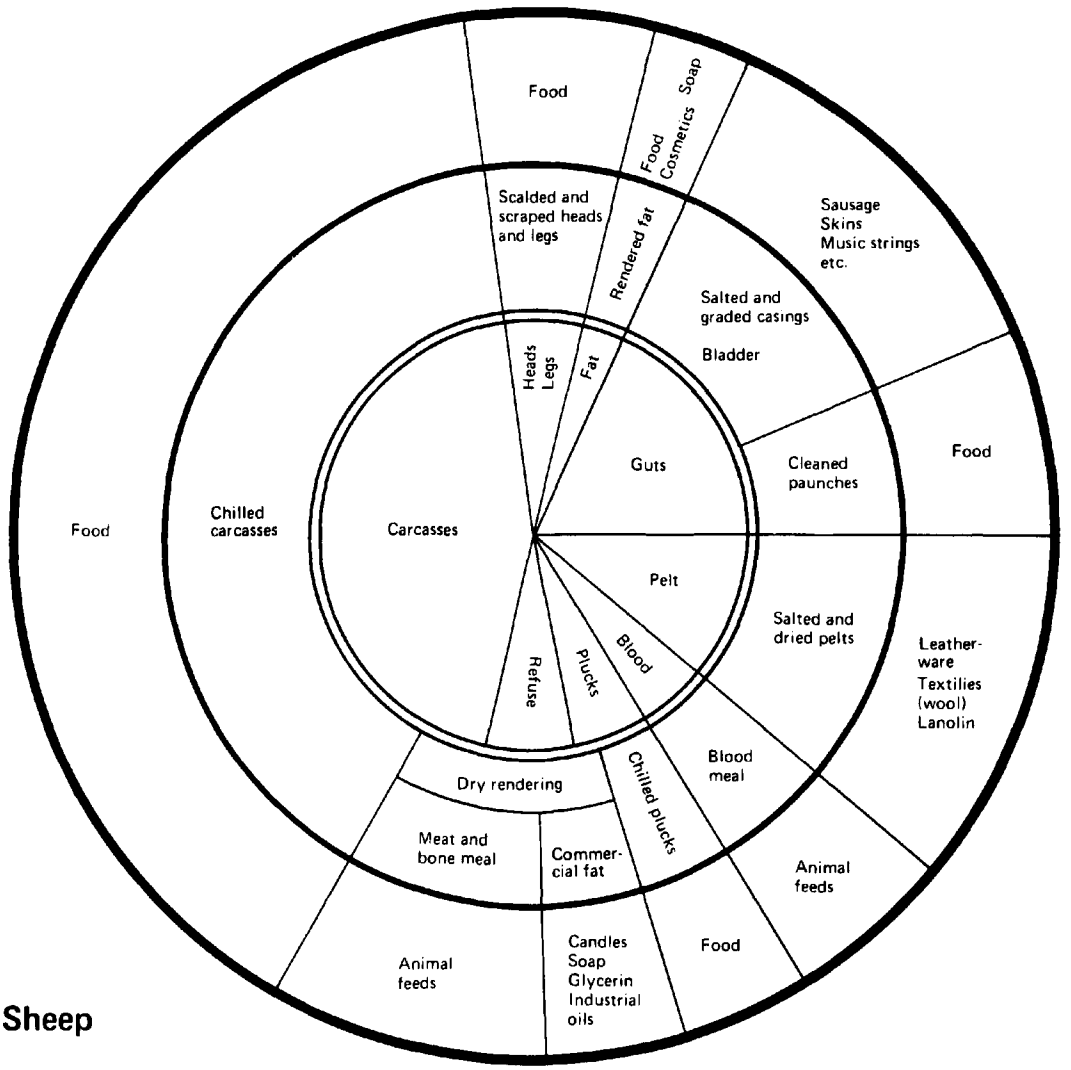


Fig. 1.4 — Division of sheep into various product categories. From Filstrup(1976).

back to the days of the Romans, and that the English used reeds stripped of the pith and plugged with grease or oil as a common method of lighting. Moulding of better candles was developed in the fifteen century in France.

In the early history of California, meat was in abundant supply and cattle were used primarily to produce by-products of hides and tallow, whereas in the Great Plains, soon after the white man came, the buffalo was used for this same purpose. Much of the tallow was converted into soap. But as America grew, beef became the primary product and the first meat packing operation was started by William Pynchon of Boston as early as 1662. By 1865, the Chicago stockyards had become the nation's livestock market and was often described as 'the busiest square mile of territory in all the world'. In the 1850s, the railroads pushed west and the great cattle-drives moved animals to the railheads. After the American Civil War, refrigerated freight cars were used by Swift, and fresh beef carcasses, rather than live animals, were transported.

H. W. Heath established the first rendering company in the United States in

Table 1.2 — Percentage of live weight of by-products from various species reported in different categories in different countries

	Cattle					Sheep		Pigs			
Country	Denmark[a]	England[b]	Sweden[c]	U.S.[d]	U.S.[e]	Denmark[a]	U.S.[d]	Denmark[a]	Sweden[c]	U.S.[d]	U.S.[f]
Carcass and other edible products	62–64					61–64		75–80			
Carcass, meat and bone			50		54–58				69	56	56
Retail cuts (bone in)				42			35				
Retail cuts (boneless)		41									
Organs			16	4	3.4–3.6		2		7	4	2.4
Red offal		6									
Bone		8									
Bone (dried weight)					1.5						
Edible fats	3–4	10	4	11		4–6	9		3	16	16
Edible fat rendered weight					1.5–2.3						
Cracklings											2.7
White offal		10									
Blood	3–4	3	3	4		3.5–4.5	4		3	4	3
Inedible raw material	8–10		5	17		6–8	22		6	8	15
Tankage (dried weight)						1.5					
Hide and/or hair	7		6	8		11–15	15		6		1
Hide (cured weight)		6			6.3–6.6						
Waste		20	16	14			11		6	12	4
Paunch and manure	8					5.5–9.5					
Shrinkage	2–10		25–30			0.5–1.5					

[a]Filstrup (1976). [b]Gerrard (1977). [c]Bengtsson and Holmqvist (1984). [d]Forrest *et al.* (1975). [e]American Meat Institute Committee on Textbooks (1958). [f]Romans *et al.* (1985).

Manchester, New Hampshire, in the late 1800s and from there the American industry expanded. Air-dried tankage was soon available as an animal protein feed substance, and cracklings supplied fat and protein to animal rations. The early to mid 1900s saw the animal by-products industry grow to tremendous proportions. The meat and by-products industry also moved further west to the source of the animals, and now centres such as Kansas City, Omaha, and St Louis became important to the meat and rendering industries.

Today, the United States meat industry generates some 30 billion pounds of inedible waste material each year that is recycled into usable products by the by-products industry.

In the United States, the animal by-products industry can be credited with the development in the country of commercial fertilizer, the use of by-products in animal feed, illustrating the importance of protein in the diet, salvaging of leather and wool for clothing and industrial use, the manufacture of soap and candles, the development of glue and gelatin, and the collection of pharmaceutical raw materials, just to mention a few.

Today, however, synthetic substitutes (i.e. imitation leather, detergents, shortenings, electrical illumination, soybean-based protein products) for many animal by-products are challenging the value of this industry and also challenging the industry to develop new products and new uses for old products, and to develop new markets.

QUANTITIES OF BY-PRODUCTS

An estimate (Filstrup, 1976; Simpson and Farris, 1982) of the world's supply of pigs is 500 000 000; cattle, 1 200 000 000; and sheep, 1 000 000 000; and the combined beef and pig population is distributed as follows:

34% Asia (20% in India but only 20% of the population eats meat)
30% North and South America
25% Europe and USSR
8% Africa
3% Oceania (contains the world's largest concentration of sheep slaughtering)

The cattle and buffalo populations in 1979 were divided according to countries as shown in Table 1.3 and meat production in different countries is categorized in Table 1.4.

The total production of by-products can be estimated from the animals slaughtered and their dressing percentages, but to separate the quantity salvaged from the amount wasted is much more difficult. Comparing the animals slaughtered, and consequently the by-products available, with the amount of by-products salvaged can clarify this relationship. The quantity and current value (1983–84) of by-products in the U.S. (see Table 1.5) and the quantity of by-products produced in England (see Table 1.6) can give some insight into the relationship in the developed countries between the availability of these by-products and those which are utilized.

Table 1.3 — World cattle inventory in 1979

Region	Head of cattle (not buffalo) (thousands)	Percentage of world cattle	Beef and buffalo meat production[a] (thousands of heads)	Percentage of world beef and buffalo meat
Africa	170110	14	2852	6
North and Central America, other than USA	63521	5	2333	5
USA	110864	9	9704	21
South America	216119	18	6865	15
Asia	366579	30	5016	11
Europe	134535	11	10508	22
Oceania	36203	3	2525	5
USSR	114086	10	6966	16
Total[b]	1212017	100	46769	100
Developed world	425019	35	31530	67
Developing world	786997	65	15239	33
(Centrally planned economics)[c]	(217751)	(18)	(11685)	(25)

[a]Indigenous production only, does not include imported animals.
[b]Totals contain an estimate for missing countries.
[c]Include part of developed and developing world.
FAO Production Yearbook (1979), Simpson and Farris (1982).

Table 1.4 — Meat production in selected countries (thousands of metric tonnes[a])

Region and country	Beef and veal		Pork		Lamb, mutton, and goat		Poultry	
	1976–80 Average	1985 Forecast	1976–80 Average	1985 Forecast	1976–80 Average	1985 Forecast	1976–80 Average	1985 Forecast
North America:								
Canada	1058	995	655	870			484	561
Mexico	1086	1381	1014	1050			395	557
United States	11043	10459	6477	6682	149	150	5987	7739
Subtotal	13187	12835	8146	8602			6866	8857
Caribbean:								
Dominican Republic	40	49						
Central America:								
Costa Rica	74	62						
El Salvador	33	30						
Guatemala	86	65						
Honduras	53	66						
Nicaragua	74	45						
Panama	45	50						
Subtotal	365	318						
South America:								
Argentina	2966	2500			126	105	201	230
Brazil	2226	2500	870	930			916	1520
Colombia	587	648	111	113				
Uruguay	345	349			32	41		
Venezuela	300	374	80	121			198	308
Subtotal	6424	6371	1061	1164	158	146	1315	2058
European Community:								
Belgium–Luxembourg	291	300	658	745	3	8	124	165
Denmark	244	236	828	1140	1	1	99	108

France	1755	1783	1505	1577	162	174	977	1277
West Germany	1463	1645	2588	2740	27	30	343	343
Greece		85		155		123		160
Ireland	386	353	138	145	41	45	45	57
Italy	1070	1180	877	1060	61	68	894	968
The Netherlands	364	500	980	1240	16	12	344	425
United Kingdom	1049	1040	913	960	241	295	757	870
Subtotal	6622	7122	8487	9762	552	756	3583	4373
Rest of Western Europe:								
Austria	187	218	345	384			59	67
Finland	109	120	155	173			13	19
Greece	106		128		119		114	
Portugal	86	97	140	173	23	23	130	154
Spain	411	420	819	1230	141	140	739	830
Sweden	151	153	306	325			41	45
Switzerland	156	161	262	292			22	26
Subtotal	1206	1169	2155	2577	283	163	1118	1141
Eastern Europe:								
Bulgaria	140	165	349	400	83	100	149	160
Czechoslovakia	421	452	808	820	7	7	181	215
East Germany	410	400	1157	1200	15	17	142	150
Hungary	151	145	884	1035	6	7	309	370
Poland	827	720	1735	1353	23	18	375	260
Romania	298	230	851	860	56	65	362	426
Yugoslavia	335	345	740	805	60	61	246	305
Subtotal	2582	2457	6524	6473	250	275	1764	1886
USSR	6827	7300	5009	6100	882	850	1832	2800
Middle East:								
Israel	22	20					149	186
Turkey	193	230			328	390		
Subtotal	215	250						

Table 1.4 — (*continued*)

Region and country	Beef and veal		Pork		Lamb, mutton, and goat		Poultry	
	1976–80 Average	1985 Forecast	1976–80 Average	1985 Forecast	1976–80 Average	1985 Forecast	1976–80 Average	1985 Forecast
North Africa:								
Egypt	246	320			71	88	112	175
Other Africa:								
South Africa, Republic of	580	581			164	180	296	555
South Asia:								
India	285	301			440	494		
Other Asia:								
China								
People's Republic of (mainland)			8700	13 300				
Taiwan	9	4	494	657			200	355
Hong Kong			34	36			41	49
Japan	376	485	1283	1485			1010	1356
Korea, Republic of	111	158	175	330			87	177
Philippines	119	175	344	450				
Subtotal	615	822	11 030	16 258			1338	1937
Oceania								
Australia	1897	1310	202	238	542	520	251	331
New Zealand	551	459			518	685		
Subtotal	2448	1769			1060	1205		
Total	41 642	41 664	42 614	51 174	4337	4697	18 624	24 299

[a]Metric tonne=2200 lb.
USDA, Foreign Agriculture Service (1984)

Table 1.5 — United States by-product trading

	Million dollars		Million lb[a]		
	Imports	Exports	Production	Export	Domestic use
Variety meat	4.4	260.6			
Tallow, grease and lard	3.8	587.2			
Lard			950	55	920
Tallow			1300	100	1225
Inedible tallow and grease	0.6	697.1	6026	3035	
Casings	52.7	19.0			
			1000 Pieces		
			Production	Export	Domestic use
Hides and skins	66.1	777.3			
Cattle hides			37500	20500	12608
Calf hides			3020		
Leather	318	275	16500		
Wool and mohair	175.4	53.3			

[a] 1lb=453.59 g.
American Meat Institute (1984), USDA (1980, 1982, 1983, 1984), U.S. Hide, Skin and Leather Association (1983a,b).

Table 1.6 — English production of animal slaughter by-products

Items	Production (thousand tons)
Blood (all animals)	100
Head meat (deboned)	147
Tongues	18
Spleen	. 6
Stomach	64
Lungs	26
Oesophagus	2
Intestines	123
Mesentery fat	69

British Food Manufacturing Industries Research Association (1978).

REFERENCES

Alfa-Laval (1984) *In the agro-food industry.* Stockholm, Alfa-Laval.
American Meat Institute (1984) *Meat facts.* Washington, American Meat Institute.
American Meat Institute Committee on Textbooks (1958) *By-products of the meat packing industry.* Chicago, Institute of Meat Packing, University of Chicago.
Bengtsson, O. and Holmqvist, O. (1948) By-products from slaughtering: a short review. *Fleischwirtsch* **64** (3) 334.
British Food Manufacturing Industries Research Association (1978) *Research*

report No. 292. Leatherhead, Surrey, British Food Manufacturing Industries Research Association.

Burnham, F. (1978) *Rendering, the invisible industry.* Fallbrook, California, Aero Publishers.

Clemen, R. A. (1927) *By-products in the packing industry.* Chicago, University of Chicago Press.

Dainty, R. B. (1981) *Darling-Delaware centenary, 1882–1982.* Chicago, Darling-Delaware Company.

FAO (1979) *Production yearbook.* Rome, United Nations Food and Agricultural Organization.

Filstrup, P. (1976) *Handbook for the meat by-products industry.* Denmark, Alfa-Laval, Slaughterhouse By-Products Department.

Food Standard Committee of the Ministry of Agriculture, Fisheries and Food (1972) *Food standards committee report on offals in meat products.* London, HMSO.

Forrest, J. C., Aberle, E. D., Hedrick, H. B., Judge, M. D. and Merkel, R. A. (1975) *Principles of meat science.* San Francisco, W. H. Freeman.

Gerrard, F. (1972) What is offal? *Meat Trades Journal,* September 14.

Gerrard, F. (1977) *Meat technology.* London, Northwood Publications.

Levie, A. *The meat handbook,* 2nd edn. Westport, Connecticut, AVI.

Mountney, G. J. (1966) *Poultry products technology.* Westport, Connecticut, AVI.

Romans, J. R., Jones, K. W., Costello, W. J., Carlson, C. W. and Ziegler, P. T. (1985) *The meat we eat.* Danville, Illinois, Interstate.

Simpson, J. R. and Farris, D. E. (1982) *The world beef business.* Ames, Iowa State University Press.

USDA. (1980) *Foreign agriculture circular: meat and livestock,* FLM-MT 8–80, Washington, USDA.

USDA, (1983) *Agricultural statistics.* Washington, USDA.

USDA, (1984) *Oil crops outlook situation.* Washington, USDA.

USDA Foreign Agriculture Service (1984) *FL and P 2–84. Carcass Weight.* Washington, USDA.

USDA Market News (1973) *Livestock marketing handbook.* Washington, Livestock Division, Agricultural Marketing Service, USDA.

U.S. Hide, Skin and Leather Association (1983a) *Report of 4th Annual Meeting.* Washington, U.S. Hide, Skin and Leather Association.

U.S. Hide, Skin and Leather Association (1983b) Compiled from official statistics of the U.S. Department of Commerce. Washington, U.S. Hide, Skin and Leather Association.

2

Edible meat by-products

INTRODUCTION

The yield of edible by-products from meat animals ranges from 20 to 30% (sometimes higher for fat animals) of the live weight for beef, pork and lamb and from 5 to 6% of the live weight for chickens (Table 2.1); therefore, more attention should be given to edible by-products.

Biologically, most non-carcass material is edible, with appropriate cleaning, handling or processing. Due to custom, religion, palatability, and reputation of the product, however, variety meat is normally limited to the liver, heart, tongue, kidney, sweetbreads, brain, tripe and sausage casings, although there are additional items salvaged and/or used in many cultures.

This non-carcass material is usually separated into categories of decreasing value such as sausage material, edible by-products, pet food, animal feed or fertilizer. The area or category into which a meat processor places a specific product depends, not only on the possible utilization of that product, but also on the availability of a potential market. Many edible by-products are down-graded because of the lack of a profitable market. Since the demand for variety meat is less than for other cuts of meat, it is usually a very economical buy. Due to this lack of demand in many producing countries and the fact that edible by-products are a very economical source of high quality protein, there is a sizable international trade in these products. An example of this may be found in Table 2.2, which shows the import and the export figures for U.S. variety meat.

Fortunately, many cooks and ethnic groups have the ability to prepare a variety of interesting variations of very delicious variety meats and are usually large consumers of this type of product. Many variety meats have excellent nutritional properties, as shown by the protein, fat, mineral and vitamin contents tabulated in Table 2.3, and the fatty acid contents shown in Table 2.4, and a few problems, as listed in the cholesterol-content figures shown in Table 2.5. In general, sausages containing by-products are often considered nutritionally superior to their all-meat counterparts.

Edible by-products, in general, due to their higher glycogen content and lesser fat

Table 2.1 — By-product yield based on live weight

	Percentage of live weight			
	Beef	Hog (pig)	Lamb	Chicken (1.4–2.3 kg (3–5 lb))
Cheeks	0.32			
Blood	2.4–6	2–6	4–9	
Blood, dried	0.7			
Brain	0.08–0.1	0.08–0.1	0.26	0.2–0.3
Chitlings	0.06			
Cracklings	3.0	2.2		
Edible kill fat	1–7	1.3–3.5	12	
Feet	1.9–2.1	1.5–2.2	2.0	
Gizzard				1.9–2.3
Hanging tender	0.19			
Head and cheek meat	0.32–0.4	0.5–0.6		
Heart	0.3–0.5	0.2–0.35	0.3–1.1	0.3–0.8
Intestines		1.8	3.3	
Kidney	0.07–0.2	0.2–0.4	0.6	
Lips	0.1			
Liver	1.0–1.5	1.1–2.4	0.9–2.2	1.6–2.3
Lungs	0.4–0.8	0.4–0.8	0.7–2.2	0.7
Pancreas	0.06	0.1	0.2	
Rennet	0.23			
Skirt	0.2–0.3	0.4–0.5	0.5	
Spinal cord	0.03			
Spleen	0.1–0.2	0.1–0.12	0.1–0.4	0.15
Sweetbread	0.03–0.05			
Heart	0.02			
Neck	0.02			
Tail	0.1–0.25	0.1		
Tongue	0.25–0.5	0.3–0.4		
Tripe	0.75–2.0	0.6	2.9–4.6	
Bible	0.18			
Plain	0.6			
Honeycomb	0.1			
Weasand	0.04–0.09	0.05		
Rendered edible fat	2–11	12–16	9	

Sources: Gerrard and Mallion (1977), Ockerman (1975), Romans *et al.* (1985).

covering are more perishable than the carcass; therefore, they must be chilled quickly, handled with a high degree of sanitation, and cooked and served as soon after slaughter as possible. The organs should be removed within 30 minutes of

Table 2.2 — U.S. variety meat, imports and exports

	Imports	Exports	
	($ million)	($ million)	(metric tonnes)
U.S. Imports and Exports in 1983			
Variety meat	4.4	260.6	
Tallow, grease and lard	3.8	587.2	
Casings	52.7	19.0	
U.S. Exports, 1984 to:			
Denmark		1.0	391
United Kingdom		15.2	18926
The Netherlands		8.9	9705
Belgium–Luxembourg		10.8	8352
France		46.1	39330
West Germany		1.4	1387
Italy		0.016	20
Greece		0.007	5
Total EEC		83.8	78116

Sources: American Meat Institute (1984), Bischoff (1985).

bleeding the animal, but usually remain with the carcass until after governmental inspection, which is normally longer than 30 minutes. The kidneys often remain with the carcass until it is cut. Reduction of temperature retards bacterial growth tremendously and Bijker (1981) illustrated a drastic increase in the bacterial growth curve when products were stored at 4°C (39°F) compared with similar products stored at 2°C (68°F). Even at 20°C (36°F) bacterial numbers were altered during 5 days' storage of beef, pork and lamb organs, as reported by Hanna *et al.* (1982). The change in bacterial numbers during this storage period expressed in $\log_{10}/cm^2$ ranged from 0.12 to 0.57 increase for livers, from −0.07 to 0.62 change for kidneys and from −0.28 to 1.18 change for hearts. The removal of the mucous membrane also reduced (approximately 10-fold) the bacterial load and this reduction seemed to be maintained during reasonable storage (Bijker, 1981). The addition of carbon dioxide snow (dry ice) to accelerate chilling of by-products on the slaughter floor greatly reduces microbiological growth in these products. Freezing is known to cause sublethal injury and death to many microorganisms in food; however, freezing (−20°C (−4°F) for 4 days) of liver, kidney and heart did not significantly decrease the bacterial numbers on these products (Hanna *et al.*, 1982). Freezing can be expected to arrest bacterial growth (R. Strange, personal communication) as long as the product remains frozen. Vacuum packaging of liver and kidneys suggested that after 7 days storage at 2°C (36°F), the bacterial level of the vacuum packages had not increased as much as the non-vacuum packaged product. This difference in bacterial levels between vacuum and non-vacuum packaged products was greater after 14 days and in many cases vacuum packaging doubled the refrigerated shelf-life of these

Table 2.3 — Range of composition of variety meat/100 g raw edible portion

	Protein (g)	Fat (g)	Ca (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit. B_6 (mg)	Pantothenic acid (mg)	Biotin (μg)	Folacin (μg)	Vit. B_{12} (mg)	Vit. A (IU)	Ascorbic acid (mg)
Beef																	
Brain	10.4–11.5	8.6	10	312	2.4	125	219	0.07–0.23	0.22–0.26	3.0–4.4	0.10–0.16	2.5	2.0–6.1	6–12	4.7–9.0	Nil	18.0–23.0
Heart	17.1–28.5	3.6	5	195–230	4.0–4.9	86–95	193–320	0.24–0.68	0.80–0.90	6.3–7.5	0.23–0.29	1.2–2.3	2.0–7.3	4–110	8.0–13.0	Trace–3.0	2.0–7.0
Kidney	15.4–24.7	2.6–6.7	10–11	219–230	5.7–7.4	176–180	225–230	0.28–0.37	1.90–2.55	5.4–6.4	0.32–0.39	3.4	24.0–92.0	41–77	28.0–31.0	690–880	10.4–15.0
Liver	20.0–22.9	3.8–7.8	6–8	352–360	6.5–7.0	81–136	281–320	0.23–0.28	3.00–3.30	13.4–21.0	0.74–0.83	5.5–8.3	33.0–100.0	81–330	65.0–110.0	12709–44000	22.4–31.0
Pancreas	17.6–27.1	7.3	8	216–330	2.8–8.4	67	276	0.14	0.34–0.55	3.1–5.8	0.20	3.8	14.0	—	4.8–5.0	Nil	13.7–14.0
Tongue	15.3–22.2	14.6	6–8	170–182	2.1–2.2	73	197–250	0.16–0.17	0.28–0.49	3.9–4.9	0.13–0.17	2.0	1.0–3.3	4	7.0	Nil	3.3–7.0
Veal Liver	19.2–21.5	4.7–7.3	7–8	333–360	8.0–8.8	73–93	281–330	0.20–0.52	2.70–3.30	11.4–16.5	0.30–0.54	6.0	39.0–75.0	46–240	100.0	13530–22500	18.0–36.0
Pork																	
Brain	10.4–12.2	8.6	10	312	2.4	125	219	0.16–0.23	0.26–0.28	4.3–4.4	—	2.8	—	—	2.8	Nil	13.5–18.0
Heart	16.8–23.5	2.7–4.4	3–6	131–220	3.3–4.8	54–80	106–300	0.31–0.48	0.81–1.24	6.6–9.6	0.29–0.35	2.5	4.0–18.0	2	2.4–8.0	Trace–106	3.0–5.0
Kidney	16.3–25.4	2.7–3.6	8–11	218–270	5.0–6.7	115–190	178–290	0.26–0.58	1.70–1.90	7.5–9.8	0.55	3.1	32.0–130.0	42	6.6–14.0	130–230	14.0–14.2
Liver	20.6–21.6	3.7–6.8	6–10	356–370	19.2–21.0	73–87	261–320	0.30–0.31	3.00	14.8–16.4	0.68	0.9	27.0	110	25.0	Nil–10900	13.0–23.0
Pancreas	28.5	4.0–15.0	—	—	18.9	—	—	0.11	0.46	3.5	—	4.6	—	—	6.5–7.0	Nil	15.0–15.3
Lamb																	
Brain	10.3–12.7	7.6–8.6	10–12	312–340	1.6–2.4	125–140	219–270	0.07–0.23	0.24–0.26	3.0–4.4	0.10	2.6	2	6	7.3–9.0	Trace	18.0–23.0
Heart	16.8–21.7	9.6	11	249	—	—	—	0.31–0.48	0.74–0.90	4.6–6.9	0.30	3.0	4	2	5.2–8.0	Trace–70	7.0–7.3
Kidney	16.8–23.1	2.7–3.3	10–13	218–260	7.4–7.6	200–220	230–270	0.38–0.51	1.80–2.40	6.8–8.3	0.30	4.3	37	31	26.0–55.0	279–690	7.0–15.0
Liver	21.0–23.7	3.9	10	349	10.9	52	202	0.27–0.40	3.30–3.90	12.0–14.2	0.37–0.42	8.1	41–130	220	35.0–84.0	50500–76756	10.0–33.0
Pancreas	14.7–23.3	7.8–19.9	8–11	282–400	1.0–2.5	44–75	217–420	0.13	0.50	3.9	—	3.5	—	—	19.0	Nil	17.5–18.0

Anon (1976), Kiernat *et al.* (1964), Ockerman (1983), Paul and Southgate (1978), USDA (1963), U.S. Meat Export Federation (2nd edition).

Table 2.4 — Percentage of fatty acids in organ fats

Fatty acid	Liver		Heart		Kidney		Brains		Spleen	
	Beef	Pork	Beef	Pork	Beef	Pork	Beef	Pork	Beef	Pork
C10 : 0	—	—	0.1	0.3	0.1	0.1	—	—	—	Tr.
C12 : 0	Tr.	—	0.1	0.2	0.1	0.1	—	—	Tr.	Tr.
C13 : 0	Tr.	0.1	—	—	—	0.1	—	—	—	—
C13 : 1	Tr.	—	—	—	—	—	—	—	Tr.	—
C14 : R	—	—	0.2	—	0.1	0.1	0.2	Tr.	—	0.1
C14 : 0	0.8	0.8	1.3	1.9	2.0	1.1	1.1	0.3	1.3	0.9
C14 : 1	0.7	0.2	0.2	—	0.4	0.1	—	—	—	Tr.
C15 : R	0.5	—	0.2	—	0.7	—	0.2	—	—	—
C15 : 0	0.7	0.5	0.3	—	0.8	0.1	2.1	0.1	0.4	0.1
C15 : 1	1.7	—	0.3	—	0.4	0.4	—	1.2	0.7	Tr.
C16 : R	—	0.7	0.6	0.3	—	—	0.2	—	—	—
C16 : 0	15.0	16.2	16.2	20.0	22.4	21.4	16.4	16.0	24.2	21.6
C16 : 1	4.1	1.3	4.3	2.5	3.5	2.2	2.0	2.0	2.9	2.8
C16 : 2	—	—	—	—	—	—	0.8	—	0.8	—
C17 : 0	1.0	0.7	0.9	0.6	0.9	0.4	0.7	0.5	1.5	1.5
C17 : 1	3.7	1.7	2.3	0.1	0.9	0.3	2.8	1.1	1.0	2.3
C18 : 0	14.7	17.7	21.2	13.5	25.0	19.0	22.3	27.1	15.0	20.2
C18 : 1	19.8	27.9	29.4	39.7	29.2	39.6	30.2	34.5	31.5	29.0
C18 : 2	10.1	12.4	7.0	9.1	5.0	8.1	2.3	1.5	6.9	7.9
C18 : 3	3.2	1.1	2.0	4.5	1.5	1.7	3.9	2.9	1.6	2.2
C19 : 0	0.3	0.7	0.6	1.5	1.7	0.6	0.6	1.1	1.4	3.0
C20 : 0	4.3	1.1	1.7	1.9	0.4	0.1	1.7	0.4	2.2	0.8
C20 : 1	—	—	—	—	—	—	—	2.2	—	0.9
C20 : 2	4.2	2.2	1.9	0.8	—	0.4	—	—	—	1.5
C20 : 3	—	2.6	0.8	1.4	—	0.7	0.6	0.7	—	—
C20 : 4	8.3	9.7	1.5	0.9	2.6	2.6	8.0	7.8	5.2	2.4
C20 : 5	6.9	2.6	4.3	0.1	—	0.4	—	—	—	0.4
C21 : 0	—	—	—	—	0.7	—	1.5	—	—	0.3
C21 : 3	—	—	—	—	—	—	—	—	2.3	—
C22 : 0	—	—	1.5	0.7	0.6	0.4	1.4	0.6	—	2.1
C22 : 4	—	—	—	—	—	—	1.0	—	1.1	—
Saturated	37.3	38.3	46.0	40.9	56.5	43.8	48.4	46.1	46.8	50.6
Unsaturated	62.7	61.7	54.0	59.1	43.5	56.2	51.6	53.9	53.2	49.4

Tr. = trace. Renon *et al.* (1980).

stored organs (R. Strange, personal communication). In vacuum packaging, lactic acid bacteria (homo- and heterofermentative lactobacilli, streptococci, *Leuconostoc* spp.) became the dominant types. With organs packaged in polyvinylchloride (non-vacuum packaged), gram-negative bacteria (i.e. *Pseudomonas* spp.) frequently

Table 2.5 — Cholesterol content

Variety meat	Treatment	Cholesterol (mg/100 g meat)
Brain	Raw	More than 2000
Heart, beef	Cooked	270
Kidney	Raw	375
Kidney	Cooked	800
Lard	Rendered	95–240
Liver	Raw	300
Liver, beef	Cooked	435
Liver, calf	Cooked	435
Liver, lamb	Cooked	435
Liver, pork	Cooked	435
Sweetbreads	Raw	260
Tongue	Raw	180
Tripe	Raw	95

Sources: Ockerman (1983), USDA (1963).

became dominant (Hanna *et al.*, 1982). In addition to being utilized fresh and frozen, a few of these items are cured and/or smoked and/or pickled and/or canned.

The characteristics, storage and preparation, types and sizes, and cooking methods of variety meat, together with a buying guide, may be located in Table 2.6.

Although variety meat utilization is reasonably uniform between species and between countries, there are a few differences. In spite of the fact that these differences tend to overlap among areas of the world, an attempt has been made to organize them into beef and veal (Table 2.7), pork (Table 2.8) and lamb (Table 2.9) for continental Europe, the United Kingdom and the United States of America. To give an indication of the percentage of by-products saved, a survey of selected U.S. packers may be found in Table 2.10.

LIVER

Liver in the beef animal is thick at the upper end, is elongated (58 × 38 cm (23 × 15 in)) and tapering; will usually average about 5 kg (11 lb) (normal range 4.5–6.0 kg (9.9–13.2 lb)) in a market weight animal, and has a thinner left lobe (called the 'thumbpiece') with a slight tail. Veal liver is similar to beef liver but is rounder and much smaller, averaging only 1.4 kg (2.5 lb), is softer in texture, has more rounded edges, has a 'thumbpiece' that is more blunted in appearance. An umbilical vein can also be seen in the veal liver. Sheep liver is similar to beef liver but smaller (25×17 cm (10×6.5 in), average 0.45 kg (1 lb) for a market weight lamb) and the 'thumbpiece' appears proportionately larger and tapers to a point. Pork liver has five lobes and tapers at the edges, and the connective tissue covering gives a 'nutmeg' (Morocco

Table 2.6 — Preparing variety meat

Kind	Characteristics	Buying guide		Storage and preparation	Type and size	Cooking			
		Average weight lb	Servings			Fry	Broiled	Braised	Cooked in liquid
Liver (Beef, veal, pork, lamb)	Veal, lamb, pork livers more tender than beef. Veal and lamb livers milder in flavour than pork and beef.	1 beef — 10 1 veal — 2.5 1 pork — 3 1 lamb — 1	¾–1 lb for four	Frozen, thaw in refrigerator. Fresh, refrigerate, use in 24 h. Grind, for loaves or patties.	Beef 3- to 4-lb piece, sliced Veal (calf) sliced Pork 3–3.5 lb whole, sliced Lamb sliced	 20 min 20 min 20 min 20 min	 8–10 min 8–10 min	 2–2.5 h[a] 20–25 min[a] 1.5–2 h[a] 20–25 min[a] 	
Kidney (Beef, veal, pork, lamb)	Veal, lamb and pork kidneys more tender than beef, also milder in flavour. Veal and lamb kidney sometimes cut with chops.	1 beef — 1 1 veal — ¾ 1 pork — ¼ 1 lamb — ⅛	4–6 3–4 1–2 0.5–1	Fresh, refrigerate, use in 24 h.	Beef Veal (calf) Pork Lamb		 10–12 min 10–12 min 10–12 min	1.5–2 h[a] 1–1.5 h[a] 1–1.5 h[a] ¾–1 h[a]	1–1.5 h ¾–1 h ¾–1 h ¾–1 h
Heart (Beef, veal, pork, lamb)	Beef heart is least tender but all hearts must be made tender by proper cooking.	1 beef — 4 1 veal — ½ 1 pork — ½ 1 lamb — ¼	10–12 2–3 2–3 1	Frozen, thaw in refrigerator. Fresh, refrigerate, use in 24 h.	Beef Whole Sliced Veal (calf) Whole Pork Lamb			 3–4 h 1.5–2 h 2.5–3 h 2.5–3 h 2.5–3 h	 3–4 h 2.5–3 h 2.5–3 h 2.5–3 h

Table 2.6 — (*continued*)

Kind	Characteristics	Buying guide		Storage and preparation	Type and size	Cooking			
		Average weight lb	Servings			Fry	Broiled	Braised	Cooked in liquid
Tongue (Beef, veal, pork, lamb)	May be purchased fresh, pickled, corned or smoked. Must be made tender by proper cooking. Pork and lamb usually purchased ready to serve.	1 beef — 3.75 1 veal — 1.5 1 pork — ¾ 1 lamb — ½	12–16 3–6 2–4 2–3	Fresh, refrigerate, use in 24 h. Smoked, refrigerate, use in 3 days. Pickled, refrigerate, use in 7 days.	beef Veal (calf) Pork Usually sold ready to serve Lamb				3–4 h 2–3 h
Tripe (Beef)	Plain and honeycomb, latter preferred. Purchased fresh, pickled or canned. Often purchased precooked; requires further cooking.	Plain — 7 Honeycomb — 1.5	¾–1 lb for four	Fresh, refrigerate, use in 24 h; usually cooked but requires more cooking. Pickled, soak before use. Canned, heat and serve.	Beef	10–15 min	10–15 min[b]		1–1.5 h
Sweetbreads (Beef, veal,	Divided into two parts: heart and throat sweetbreads.	Veal Neck and heart pair — 1	¾–1 lb for four	Frozen, thaw in hot water,	All types	Deep fat 10 min[b]	10–15 min[b]	20–25 min	15–20 min

lamb)	Tender and delicate in flavour.	Pieces — ¾ oz Beef Neck only Lamb — 2 oz		Fresh, refrigerate, use in 24 h.				
Brains (beef, veal, pork, lamb)	Very tender and delicate in flavour; veal most popular.	Beef — ¾ Lamb — ¼ Pork — ¼	¾–1 lb for four	Frozen, thaw in hot water. Fresh, refrigerate, use in 24 h.	All types	10–15 min[b]	20–25 min	15–20 min
Oxtail (Beef)	Large portion bone, fine meat flavour. Disjointed.		1 lb for two	Frozen, thaw in refrigerator. Fresh, refrigerate, use in 24 h.	Beef			Simmer 2 h or until tender.
Giblets (Poultry)	Heart, liver, gizzard and sometimes neck.	3–4 Chicken Liver — 2 oz Heart — 0.5 oz Gizzard — 0.1 lb	1 lb for four	Frozen, thaw in refrigerator. Fresh, refrigerate, use in 12 h.	Chicken liver — 10 min			Simmer until tender. Liver 10–15 min. Gizzard and Heart: young chicken — 30 min; old chicken — 1 h turkey — 1.5–2 h.

[a] On top of range or in a 149–163°C (300–325°F) oven.
[b] Time required after precooking in water.
1 lb = 454 g. McLean and Campbell (1952), National Live Stock and Meat Board (1974a,b), Ockerman (1975).

Table 2.7 — Edible beef and veal by-products

By-products	Used in Continental Europe	Used in United Kingdom	Used in United States
Blood	Blood food preparation Blood sausage	Black pudding Blood and barley loaf Sausage ingredient	Sausage ingredient
Blood plasma			
Bone	Gelatin Soup	Gelatin Soup	Gelatin Jellied products Refining sugars Soup
Brain	Poach (warm or cold) Fry	Broil Sauce Liver sausage	Precook in water Broil Scramble Fry Cream
Cheek and Head trimmings	Cooked sausage Cold with vinegar sauce	Stew Processed meat Brawn	Sausage ingredient
Extract	Soup Bouillon	Soup Bouillon	Soup Bouillon
Fat			
Oleo stock			
Oleo oil	Shortening	Drippings Shortening	Oleomargarine Shortening
Oleo stearin	Shortening	Shortening	Sweets Chewing Gum Shortening
Edible tallow	Shortening Mincemeat	Paste Pudding Mincemeat	Shortening
Feet	Jelly	Cow heel Foot jelly	Jelly
Heart	Stew Fry Stuff	Bake Boil Processed meat	Braise Cook in liquid Loaf Patty Sausage ingredient
Intestine, large	Sausage casing	Sausage casing	Sausage casing
Intestine, small	Sausage casing	Sausage casing	Sausage casing
Kidney	Stew Fry	Stew Pie Soup	Braise Broil Cook in liquid Patty Loaf
Liver	Fry (warm) Boil (cold) Grill (warm) Sausage	Braise Liver sausage	Braise Fry Broil Loaf Patty Sausage ingredient
Oesophagus	Sausage ingredient	Sausage ingredient	Sausage ingredient
Oxtail	Soup	Soup Stew	Soup
Skin trimmings	Gelatin	Gelatin	Gelatin Jellied food
Skirt, thick	Stew Sausage ingredient	Stew Sausage ingredient	Stew Sausage ingredient

Continued next page

Table 2.7 — *continued*

Spleen	Blood preparation	Pie Flavouring Melt	Variety meat
Stomach			
Rumen	Tripe Sausage ingredient	Tripe Sausage ingredient	Tripe Sausage ingredient
Reticulum	Tripe Sausage ingredient	Honeycomb tripe Sausage ingredient	Tripe Sausage ingredient
Abomasum	Sausage ingredient	Red or black tripe Sausage ingredient	Sausage ingredient
Calf	Tripe Rennet	Rennet	Rennet
Sweetbread			
Thymus	Cook in sauce Poach, with sauce Fry Stew	Fry Boil	Precook in water Broil Fry Braise Cream Variety meat
Pancreas	Cook in sauce	Gut bread	Precook in water Broil Fry Braise Cream Variety meat
Tongue	Boil (warm or cold) Cure, smoke, cook	Salt and boil Sausage ingredient Cure, smoke, cook	Cook in liquid Sausage ingredient Cure, smoke, cook
Udder	Boil Fry	Boil Salt Smoke Fry	

leather) appearance, making even a small piece easily species-identifiable. Pork liver usually averages approximately 1.4 kg (3 lb) (25 × 23 cm (10 × 9 in)) on a market weight animal (3.2 kg (7 lb) for a mature sow).

Livers are removed on the slaughter floor, gall bladder (pear to cigar-shaped) and the bile duct are carefully removed to prevent the yellow, bitter-flavoured bile from contaminating the liver, and the liver is washed and quickly chilled. The liver may be packaged and shipped to the retail market in this condition or the capsula fibrosa, large blood vessels and ducts along the external surface of the liver may be removed, often by a mechanical skinner which contains a stationary blade above a rotating burred drum. Small portions of the capsula fibrosa often remain on the edges and in the creases of the liver. The 'thumbpiece' may be removed during the skinning of the liver. This skinning operation may be accomplished at the point of origin, at the retail level, or by the consumer. Livers may be frozen, but beef liver becomes softer due to freezing and freeze–thaw fluctuations. The quality of frozen stored livers decreases with increasing storage temperatures, increasing storage times and non-vacuum packaging (Pierson, 1982).

Studies on beef liver at the supermarket (Shelef, 1975) have indicated a microbiological level of 10^5/g consisting of gram-positive cocci, spore-formers,

Table 2.8 — Edible pork by-products

By-products	Used in Continental Europe	Used in United Kingdom	Used in United States
Blood	Blood food preparation	Black pudding	Sausage ingredient
Blood plasma	Blood food preparation	Sausage ingredient	Sausage ingredient
Bone	Gelatin	Gelatin	Gelatin
	Mechanically deboned tissue	Mechanically deboned tissue	Jellied products
			Rendered shortening
			Mechanically deboned tissue
Brain	Poach	Fry	Precook in water
	Fry	Braise	Broil
			Scramble
			Fry
			Cream
Cheek and Head trimmings	Sausage ingredients	Bath chap	Sausage ingredients
Ears	Stewed with feet		
Fat	Lard	Lard	Shortening, lard
Feet	Blood preparations	Cook in liquid	Pickled
	Liver preparations		Cook in liquid
	Jelly preparations		
	Boil		
	Fry		
Head	Sausage ingredient	Boar's head	Sausage ingredient
	Jelly (cold)	Salt, boil	
	Blood sausage	Brawn	
	Liver sausage	Sausage ingredient	
	Pie		
Heart	Blood preparation	Braise	Braise
	Sausage ingredient	Luncheon meat	Cook in liquid
			Loaf
			Patty
			Sausage ingredient
Intestine, large	Chitlings	Chitlings	Chitlings
	Sausage casing	Sausage casing	Sausage casing
Intestine, small	Sausage casing	Sausage casing	Sausage casing
Kidney	Fry	Grill	Braise
		Stew	Broil
		Soup	Cook in liquid
			Patty
			Loaf
Liver	Liver food preparation	Pates	Braise
	Processed meat	Stew	Fry
	Pates	Fry	Broil
	Boil (cold)	Liver sausage	Loaf
	Fry		Patty
			Sausage ingredient
Lung	Blood preparation	Pet food	Pet food
Oesophagus	Sausage ingredient	Processed meat	Sausage ingredient
Omentum	Covering for processed meat	Covering for meat pie	Covering for processed meat
		Covering for pate	
Skin	Rind emulsion	Rind emulsion	Gelatin
	Gelatin	Gelatin	Jellied food products
	Rind	Rind	French-fried pork skin
Spleen	Fry	Pig's fry	Variety meat
	Blood sausage	Flavouring	
		Pie	
		Melt	

Contined on next page

Table 2.8 — *continued*

Stomach		Sausage ingredient	Sausage ingredient
		Sausage casing	Sausage container
Stomach, tripe			Precook in water
			Braise
			Fry
			Boil
Tail	Hotchpot	Salt and boil	Boil
Tongue	Cured, boil	Salt and boil	Cure, smoke, boil
	Sausage ingredient	Sausage ingredient	Sausage ingredient
	Blood–tongue sausage		
	Liver–tongue sausage		
	Tongue salad		
	Tongue with jelly		
	Processed meat		

coliform bacteria and gram-negative rods. After 7–10 days of storage at 5°C (41°F) these livers were unacceptable, with counts of $7–8 \times 10^7$/g, and lactic acid bacteria were the predominant type. Lactic acid bacteria are also the predominant type in vacuum-packaged liver, and consequently a pH value on vacuum-packaged liver below 6.0 often suggests spoilage (Shelef, 1975).

The liver is often thin-sliced and cooked by a variety of techniques (Table 2.6). Liver may be ground and incorporated into many dishes, loaves, spreads and sausages. For example, braunschweiger, liver cheese, liver loaf, liver mush, liver paste, liver paste with truffles, liver pudding, liver sausage, liver spread and liverwurst (for composition see Table 2.11) must all have a minimum of 30% fresh liver if produced under USDA inspection. For example, braunschweiger is often made from 50% liver which is combined, individually or in combination, with fresh or smoked pork jowls and/or 50/50 pork trimmings. The livers are placed in a meat chopper and chopped until bubbles appear (approximately 10 min) and then the pork jowls and/or pork trimmings which have been ground through a 6.4 mm ($\frac{1}{4}$ in) grinder plate are added to the chopper. Two and one-half percent salt, 0.3% onion powder and 0.25% sugar are added. The following quantities per 45.4 kg (100 lbs) of meat are also blended into the emulsion: 4.2 g (0.15 oz) sodium nitrite, 24.1 g (0.85 oz) sodium erythorbate, 7.1 g (0.25 oz) white pepper and 14.2 g (0.5 oz) of each of the following spices: allspice, cloves, sage, marjoram, nutmeg and ginger. This mixture is chopped until no fat specks are visible in the emulsion. The product is then stuffed into a 7.0 to 7.6 cm ($2\frac{3}{4}$ to 3 in) casing and then submerged in cooking water (82°C) (180°F) and cooked in 71°C (160°F) water to an internal temperature of 67°C (152°F). The sausage is then chilled in ice water to 43°C (110°F) and then chilled to 7°C (45°F) in a cooler. Liver has poor binding quality, high collagen content and high colour parameters.

Livers can also be converted to a uniform-shaped loaf (Percel, 1979) by trimming, curing (5% pump with 82.5% water, 10.6% brinesalt (0.6% sodium nitrite and 99.4% salt), 6.4% phosphate and 0.5% sodium ascorbate), massaging (with 20% additional brine) for 2 hours, and being placed in spring-loaded moulds, cooked in a 75°C (167°F) water-bath for 3 hours, cooled in tap water for 2.5 hours, vacuum packaged and chilled in a 1°C (34°F) cooler.

Table 2.9 — Edible lamb by-products

By-products	Used in Continental Europe	Used in United Kingdom	Used in United States
Blood	Blood sausage	Black pudding	Sausage ingredient
Blood plasma		Sausage ingredient	
Bone	Mechanically deboned tissue	Mechanically deboned tissue	Jellied products
	Soup	Soup	Mechanically deboned tissue
			Soup
			Gelatin
Brain	Poach	Poach	Precook in water
	Fry	Fry	Broil
			Scramble
			Fry
			Cream
Cheek and Head trimmings	Boil, vinegar or tomato sauce	Boil	Sausage ingredient
		Sausage ingredient	
Fat			
Oleo stock			
Oleo oil		Shortening	Oleomargarine
		Dripping	Shortening
Oleo stearin			Sweets
			Chewing gum
			Shortening
Edible tallow		Shortening	Shortening
		Dripping	
Feet	Jelly	Jelly	Jelly
Heart	Roast	Stuff	Braise
	Braise	Roast	Cook in liquid
	Sausage ingredient	Braise	Loaf
		Luncheon meat	Patty
			Sausage ingredient
Intestine, large	Sausage casing	Sausage casing	Sausage casing
Intestine, small	Sausage casing	Sausage casing	Sausage casing
Kidney	Fry	Stew	Braise
	Boil	Soup	Broil
	Grill		Cook in liquid
			Loaf
			Patty
Liver	Fry	Fry	Braise
	Grill	Grill	Fry
	Sausage ingredient	Braise	Broil
		Liver sausage	Loaf
			Patty
			Liver sausage ingredient
Lungs		Haggis	Pet food
		Pet food	
Oesophagus	Sausage ingredient	Sausage ingredient	Sausage ingredient
Spleen	Blood sausage ingredient	Pie	Variety meat
		Melt	
Stomach		Honeycomb tripe	
		Container for haggis	
Sweetbread	Poach with sauce	Fry	Precook in water
	Fry		Broil
			Fry
			Braise
			Cream
Testicles		Fry	Fry
		Grill	
Tongue	Boil	Boil	Cook in liquid
	Stew	Jelly	
	Jelly (cold)		

Raw liver, desiccated liver and liver extract have long been used as a source of vitamin B_{12} and as a nutritional supplement used in treating various types of anaemia. For the composition of some modified liver products see Table 2.12.

HEART

Beef hearts are conical in shape (24 × 20 cm) (9.5 × 8 in) and average approximately 1.4 kg (3 lb) (normal range 1.4–2.0 kg (3.0–4.4 lb) from a market-weight animal). They contain three furrows (ventricular grooves) usually filled with white fat (in old cows, it may be yellow) and additional white fat is often attached to this fatty material. There are two cartilages (bone–os cardis) present in the aortic fibrous ring. The cap-on heart has the cartilage (bone–os cardis) removed but the left and right auricles remain with the heart. With the cap-off heart, the cartilages, the left and right auricles, the aorta, the pulmonary trunk and some of the fat tissues are removed. The defatted heart is a cap-off heart with fat removed in excess of 5% of the heart weight. Veal heart is similar to beef heat but smaller (average (227 g) ($\frac{1}{2}$ lb)). Pork heart is smaller (14.0 × 8.9 cm (5.5 × 3.5 in) average (227 g) ($\frac{1}{2}$ lb)) than beef heart, has two coronary furrows, contains soft white fat, and is denser in texture and more pointed than calf heart. It is usually sold with the left and right auricles left on, but can be specified with cap-off and with the desired degree of fat trim. Lamb heart is similar to pork heart but smaller in weight (average 113 g ($\frac{1}{4}$ lb) for a market weight animal) and usually the ossa cardis is absent.

The hearts are separated from the lungs on the slaughter floor and are sometimes slashed open for inspection and removal of clotted blood. The cartilages and some of the fat tissues are also usually removed at this stage of operation.

The heart is less tender than the liver and requires long-term moist cooking (Table 2.6). It can also be diced and added to stews, or ground and added to other meat for additional flavour. The cavities of the heart may be filled with dressing and the heart then roasted. Hearts are merchandized fresh or frozen, or used in processed luncheon meat where they are not only a good source of high-quality protein but, due to their high myoglobin content and high colour value, also add colour to the finished product. Hearts have a low to medium bind value and are average in collagen content. The water : protein ratio of hearts is shown in Table 2.13.

TONGUE

Beef tongue is thick 38 × 10 cm (15 × 4 in), averaging 1.7 kg (3.7 lb) for short-cut tongue, normal range is 1.2–1.7 kg (2.6–3.7 lb), tapering, rough (horny at the tip) and pointed, with six or more circumvallate papillae on each side. It may be white, black or variegated and frequently has black spots. Tongues are graded according to surface integrity as unbroken (No. 1) or broken (No. 2). The tongue may be sold as long-cut (averaging 2.3–3.1 kg (5–6.75 lb)), which is the complete tongue with the root, even including the third tracheal ring trimmed but with the larynx and the epiglottis remaining attached. The oesophagus, the pharynx and the great cornu bone or cartilage (other hyoid bones or cartilages are left in) are removed. The square-cut beef tongue is the whole organ with the base cut parallel to the blade body, and with the tip of the epiglottis and the hyoid bones or cartilages (except the great cornu bone or cartilage) attached. The larynx, trachea and fat on the base that is parallel to the blade are removed. The base retains trimmable fat and glands. The beef short-cut tongue (averaging 1.6–2.3 kg (3.5–5 lb)) is separated from the root

Table 2.10 — Percentage of selected U.S. packers saving edible by-products

Item	Percentage among those responding for each species						Market percentage for all species	Foreign markets in order of decreasing value[c]
	Beef[a]		Pork[a]		Lamb[b]			
	Saving	Not saving	Saving	Not saving	Saving	Not saving		
Bladder	20	80	—	—	—	—	50% U.S. 50% foreign	SP
Bones	60	40	27	72	72	28	100% U.S.	
Brains	50	50	50	50	28	72	35% U.S. 15% foreign 50% both	E, Af
Bung	—	—	9	91	—	—	9% U.S. 91% both	?
Cheek/head meat	100	0	100	0	50	50	96% U.S. 4% both	?
Ears	—	—	90	10	—	—	44% U.S. 55% both	CA, SP, C
Edible fat and oil	64	36	100	0	20	80	67% U.S. 33% both	E, CA, C, SA, ME
Feet	40	60	82	18	—	—	54% U.S. 46% both	CA, SA, C
Hanging tenders	100	0	72	28	—	—	42% U.S. 5% foreign 58% both	SP, As, C, ME
Whole head	20	80	9	91	88	12	100% U.S.	
Hearts	100	0	100	0	100	0	49% U.S. 5% foreign 46% both	C, E, CA, SA
Humps	12	88	—	—	—	—	100% U.S.	
Intestines	50	50	45	55	85	15	69% U.S. 6% foreign 25% both	E, SP, C, A
Kidney	100	0	91	9	100	0	40% U.S. 24% foreign 36% both	E, C, ME, CA, SA, Af
Liver	100	0	100	0	100	0	28% U.S. 4% foreign 68% both	E, ME, C, CA SA, Af, As, SP
Salivary glands	80	20	—	—	—	—	75% U.S. 25% both	CA
Skirts	70	30	—	—	—	—	14% U.S. 14% foreign 72% both	SP, E
Snouts/lips	100	0	91	9	—	—	40% U.S. 10% foreign 50% both	CA, C, E

Continued on next page

Table 2.10 — *Continued*

Spleen	91	9	73	27	50	50	75% U.S. 25% both	E, C, CA
Stomach/tripe	91	9	82	18	—	—	49% U.S. 12% foreign 39% both	CA, SP, As, E, SA
Sweetbreads	91	9	—	—	—	—	30% U.S. 20% foreign 50% both	E, CA, SP
Tail	100	0	91	9	—	—	57% U.S. 43% both	CA, E, C, ME, SA
Tendons	40	60	—	—	—	-	75% U.S. 25% both	SP, A
Testicles	100	0	—	—	88	12	88% U.S. 12% both	E
Tongue	100	0	100	0	100	0	50% U.S. 13% foreign 37% both	E, SP, CA, As, ME
Weasand	100	0	27	73	—	—	64% U.S. 22% foreign 14% both	SP, As
Pancreas	100	0	—	—	—	—	100% U.S.	
Lungs	100	0	—	—	—	—	100% U.S.	

[a]Eleven packers
[b]Eight packers
[c]Af, Africa; As, Asia; C, Canada; CA, Central America; E, Europe; ME, Middle East; SA, South America; SP, South Pacific.
University of Illinois and National Livestock and Meat Board (1986).

Table 2.11 — Percentage composition of some sausages that contain by-products

Components	Liverwurst	Pate, canned	Headcheese	Blood sausage
Moisture	52.1	53.9	64.7	47.3
Food energy (kcal)	326	319	212	378
Protein	14.1	14.2	16.0	14.6
Total fat	28.5	28.0	15.8	34.5
Carbohydrate	2.2	1.5	0.4	1.3
Fibre	—	—	0.0	—
Ash	3.1	2.2	3.1	2.3

USDA (1980).

Table 2.12 — Composition of enzymatic hydrolysis

	Nitrogen in dry matter %	Fat in dry matter %	Percentage of total nitrogen in		
			Protein	Polypeptide	Free amino acid
Paste (20–30% moisture)					
Liver	61.0	1.7	12.8	56.3	28.4
Rumen	62.0	1.7	26.5	49.5	22.0
Dry powder (8–10% moisture)					
Liver	79.0	2.3	9.5	54.6	33.6

Mitsyk *et al.* (1972).

Table 2.13 — Water : protein ratio

Meat by-product	Average reported or maximum allowed in U.S.
Broth	135 : 1
Heart, beef	4.4 : 1 (Ave)
Heart, pork	4.8 : 1 (Ave)
Luncheon meat	
Hearts and tongues, 0.1–20%	3.8 : 1
20.1–40%	4.1 : 1
40.1–60%	4.3 : 1
Potted meat food product	
Tripe, 0.1–25%	5.0 : 1
25.1–50%	5.4 : 1
50.1–75%	5.8 : 1
Stock, beef	135 : 1
Stomach, pork	4.2 : 1 (Ave)
Tongue, beef	4.4 : 1
Tongue, beef, cured	4.4 : 1
Tongue, beef, cooked, smoked and/or dried	4.4 : 1
Tongue, pork	3.9 : 1 (Ave)
Tripe, beef, cooked	5.1 : 1 (Ave)
Tripe, beef, raw	5.2 : 1 (Ave)
Tripe, beef, scalded	6.3 : 1 (Ave)

and gullet in front of the epiglottis and behind the thyroid process of the hyoid bones or cartilage (the hyoid bones or cartilages are clipped and left in, but the great cornu bone or cartilage is removed) and the tip of the epiglottis, the larynx, the trachea, and the salivary glands (except sublingual) are removed. The base of the tongue is trimmed to the false lean with only approximately 10% trimmable fat remaining. The Swiss-cut beef tongue has all the hyoid bones or cartilages, muscular root and base muscles removed, as well as most of the fat, leaving a tongue containing 95% lean and consisting of a deboned, defatted, blade body.

Tongue root is derived from the long-cut tongue when preparing the short-cut tongue after removal of the larynx, the remnant of trachea and the epiglottis. No hyoid bones or cartilages remain in the root.

Veal tongue is similar to beef tongue but is smaller and averages 0.7 kg or 1.5 lb for the short-cut tongue.

Pork tongue has an extended tongue shape which is triangular in cross-section, red in colour, and has a ridge extending along its length where the omentum is attached. It averages 0.3 kg or $\frac{3}{4}$ lb (16.5 × 5.1 cm) (6.5 × 2 in). The short-cut pork tongue has the root cut behind the hyoid bones, which remain with the tongue, and the trachea and the root are removed. The great cornu, the larynx and the epiglottis are also removed, but the mucous membrane between the epiglottis and the tongue remains. The pork blade-only tongue (green or unscalded) is the tongue blade remaining after removal of the great cornu, hyoid bones or cartilages, larynx, epiglottis, trachea and most of the fat (95% lean), yielding a deboned, defatted blade body. The pork blade-only tongue (scalded–scraped) is trimmed like the green or unscalded blade-only tongue, but the tongue blade is scalded and scraped to remove the mucous membrane as completely as possible.

Lamb tongue is short, smooth, thick, often black, and averages 0.2 kg or $\frac{1}{2}$ lb (8.9 × 3.0 cm) (3.5 × 1.2 in). The underside on both sides at the tip tends to have grooves and there is a depression running along the centre. The long-cut lamb tongue is the whole tongue with root attached. It contains the larynx, the epiglottis, the first three rings of the trachea and all of the hyoid bones or cartilages, except the great cornu bone or cartilage which is removed. The oesophagus and the pharynx are also removed. The root is trimmed, even including the third tracheal ring. The short-cut lamb tongue is cut from the root and is trimmed, with the tip of the epiglottis left intact, but with the pharynx, the oesophagus, the great cornu bone or cartilage (other hyoid bones or cartilages are left in) and the trachea removed. The trimmable fat of the glosso-epiglottal fold and of the glands remains on the sides and on the base of the tongue. Lamb special-trim tongue is the portion of the tongue remaining after removal of the tip of the epiglottis, the pharynx, the trachea, all hyoid bones or cartilages and the salivary glands from the sides.

If not removed prior to being received by the consumer, the tough outer membrane of the tongue can be removed more easily by blanching with a short submersion period in boiling water. Tongue is rather tough and should be cooked by long-term, moist-heat cookery (Table 2.6). In addition to being available fresh, tongue may be purchased pickled (corned), smoked or canned; the water : protein ratio is shown in Table 2.13. Smoked or pickled tongue may require soaking prior to cooking. The tongue is sliced, served hot or cold — often with garnishes or with sweet or sour sauce, horseradish, mustard sauce, or spicy sauces or dressings — and may also be added to casseroles and salads.

Beef tongues may be brine-cured by the long immersion-cure method. This is accomplished by rinsing the tongue and chilling it for 24 hours, trimming it closely, placing the tongue in an 80° (80% of saturation) brine for 24 hours, and then placing it in 26.5–30.3 l (7–8 gallons) of 80° (80% of saturation) sweet-pickle brine per 45.4 kg (100 lb) of tongue. The product is cured at 2–3°C (36–38°F) for 5 days and then overhauled, with additional salt being added to the cure, and cured for 8 or more days depending on the size of the tongue. The curing shrinkage is normally 0.5–3%. Many tongues today are artery-cured using the two lingual arteries located at the base of the tongue. The tongue should not be hung by a hook at the tip since this interferes with brine distribution and tends to mark the tongue tissue. A 5% (weight) cure is injected into each artery (total of 10% pump or 10% pick up in cure) and the following mixture is often used: 378.5 l (100 gallons) of water, 45.4 kg (100 lb) of salt, 680 g (1.5 lb) of sodium nitrite, 680 g (1.5 lb) of sodium nitrate and 2.5 kg (5.5 lb) of sodium erythrobate (isoascorbate). The tongues are then placed in the same cover pickle as that used for pumping and are allowed to cure for 3 days at 3°C (38°F). Tongues are also sometimes smoked and cooked (82°C, 180°F for 5–6 hours depending on size). Unsmoked tongues are frequently shipped in 70–80° pickle.

Cured tongues are often canned. They are first soaked 12 hours, covered with water and boiled 1.5–2.5 hours, which results in an average of 32% shrinkage. Cooking water may be utilized for manufacturing meat extract. The mucous membrane of the tongue is removed and the tongue is re-trimmed, losing an average of 3.5% shrinkage. Cans are usually stuffed by hand, with agar solution (1–5%) added, capped, then sealed under vacuum and processed under pressure. Cooking pressure and time depend on the can size. Komarik *et al.* (1974) suggest that a 1.4 kg (48-oz) can should be processed for 2.5 hours at 110°C (230°F) and then rapidly cooled.

Tongues may be jellied by curing, water cooking, and grinding; by adding gelatin, seasoning, and cooking stock; or by stuffing, placing in moulds, covering the moulds, pressing and chilling them, which produces a very perishable jellied product.

Potted tongues are produced in a similar fashion except the product receives a very fine grind after cooking, is mixed with seasoning and is then canned and processed.

Tongue is also used as an ingredient in luncheon meat. It has a medium to low bind character, a high collagen content and an average colour value.

KIDNEY

Animals have two kidneys. In beef animals the kidney is very dark brown in colour, is 22.9 × 10.2 cm (9 ×4 in), is contained in the kidney knob (suet, fat), contains 15–25 lobes and, in a market-weight animal, averages approximately 454 g (1 lb) each (normal range 0.4–0.6 kg (0.9–1.3 lb)). When the beef animal changes from a milk diet to a roughage diet and the stomachs (four) increase in size, this displaces the kidney knob to the right and toward the tail and causes a slight rotation of the left kidney (three-sided and movable). For this reason the left side of the carcass is termed the 'raison' or 'open' side and usually contains less kidney suet (fat) than

the right side ('closed') that contains an elliptical kidney which is fixed to the abdomen. Beef kidney is usually sold whole, with the blood vessels, the ureter and the capsule membrane removed, or, is sold defatted, when it has the blood vessels, the ureter, the capsule membrane and the fat deposits in the fold of the kidney removed.

Veal kidney is similar to beef kidney except it is smaller in weight (averages 340 g ($\frac{3}{4}$ lb)) and is sometimes left as part of the loin to produce veal kidney chops.

Pork kidney is single-lobed, flat, bean-shaped 10.7 × 5.1 cm (4.2 × 2 in), reddish-brown in colour, is encased in a kidney knob and averages 113 g ($\frac{1}{4}$ lb) in a market-weight animal. Pork kidney is usually sold whole, with just the blood vessels, ureter and capsule membrane removed.

Sheep kidney has one, bean-shaped 8.9 × 5.1 cm, (3.5 × 2 in) lobe, dark brown in colour, also contained in a fat kidney knob and is smaller than pork kidney. It averages 57 g ($\frac{1}{8}$ lb) in a market-weight lamb. The kidneys are also sometimes left in the loin to produce kidney chops or English lamb chops. They may also be removed and sold as whole kidneys with the blood vessels, ureter and capsule membrane removed.

Kidneys may be included as an ingredient in meat casseroles, stews or pies. Lamb and veal kidneys are usually more tender than beef kidney and may be broiled or wrapped in bacon and cooked on a skewer. Beef kidney should be cooked in liquid or braised (Table 2.6). Kidney is low in bind character and high in collagen content and colour value.

SWEETBREADS

Sweetbreads are obtained from calves, lambs and young cattle; three different tissue locations in these animals are sometimes labelled 'sweetbreads'. The whitish-yellow, lobulated thymus consists of two pairs. One portion (average 57 g ($\frac{1}{8}$ lb), normal range 0.05–0.23 kg (0.11–0.51 lb)) is located in the cervical region in the neck adjacent to the trachea and is termed 'neck bread', 'throat sweetbread' or 'throat-bread', and the other is in the thorax region and is labelled 'heart bread' or 'heart sweetbread' (normal range 0.05–0.1 kg (0.1–0.2 lb)). The thymus tissue is large and active during animal growth, but degenerates and is replaced by fibrous tissue after the animal has matured; therefore, the thymus is only available from younger animals.

The brownish-yellow, lobulated pancreas is often sold as 'gut bread'. Its function is to secrete digestive fluids, and the gland is separated from the liver and duodenum on the slaughter floor. It weighs approximately 170 g ($\frac{3}{8}$ lb) in market weight beef animals and 85 g ($\frac{3}{16}$ lb) in sheep and pigs.

The thymus sweetbreads (Table 2.6) are tender and delicately flavoured, but are very perishable and should be frozen or precooked (simmer 30 minutes in acid (1 tablespoon of lemon juice or vinegar per 946 ml (quart)) water) unless used immediately. The membrane from the sweetbreads should be removed (if liquid-cooked, after cooking) and the sweetbreads may be scrambled (often with eggs), reheated in sauce, breaded and deep fat fried, used in salads or coated with butter and broiled (Block, 1977). They are also low in bind character and colour value and high in collagen content.

TRIPE

Tripe is produced from the first (rumen, paunch) and second stomachs (reticulum) of cattle. It is called plain (averages 3.2 kg (7 lb)) and honeycomb (averages 680 g (1.5 lb), preferred), respectively. The omasum ('bible') is difficult to clean and deteriorates quickly. Therefore, it is usually not used for human food but is rendered. The brown, almost furry, 'raw unscalded' beef tripe is the paunch (in some countries it includes the paunch honeycomb) which has been cold-water flushed to remove its contents. The cream-coloured, scalded (denuded) beef tripe is the paunch (rumen) with or without the honeycomb (reticulum) which has been hot-water washed (50–55°C (122–131°F)) washed (15–20 minutes) with diluted soda water (lime water) and the dark internal lining has been scraped and removed. The white honeycomb (reticulum) beef tripe has been hot-water washed with soda ash or lime or washing soda, and the dark internal lining has been removed by scraping. 'Tripe, cooked' is the scalded tripe that is cooked to specifications and 'tripe, cooked and bleached' is cooked tripe that is further bleached and neutralized with approved chemicals. The dark cream-coloured mountain-chain beef tripe is the muscular pillars, corresponding to the grooves on the exterior side, which have been washed in cold water (they are neither scalded nor treated with chemicals). The mountain-chain tripe is usually produced from mature cattle. Sheep stomach can be processed in a manner similar to beef and will yield approximately 1 kg (2.2 lb) of tripe.

The pork stomach is available as 'whole unscalded' (light to medium brown in colour) in which the whole stomach is inverted, cleaned and trimmed; and, if so specified, the lining may be removed. The pork stomach is also available in the scalded form (cream to light brown in colour) in which the whole stomach is inverted, cleaned, trimmed and scalded; and, if so specified, the lining may also be removed.

Tripe (Table 2.6) is sometimes precooked (in water) and sometimes fully-cooked and may be packed in vinegar, pickled or canned. The clean stomach is manufactured into tripe by cutting to the appropriate size and pickling in 60° salt brine, or cooking and pickling in a weak salt and vinegar brine.

The water : protein ratio of various types of tripe is shown in Table 2.13. The precooked (usual form) tripe requires further salt-water cooking, may be served with sauces or dressings, or used in meat casseroles, stews or pies. Tripe is delicately flavoured and is often served with tomato sauce, buttered and broiled, covered with dressing and baked, dipped in butter and sauteed, or added to a thick soup. Tripe is low in bind character and colour and high in collagen content.

BRAINS

The brains of beef (average 454–482 g (16–17 oz)), veal, pork (average 113–127 g (4–4.5 oz)) and lamb (average 127–142 g (4.5–5 oz)) are removed from the skull on the slaughter floor. The 'whole pork brain' containing the cerebellum, cerebral hemisphere, thalamus, and pons is separated from the spinal cord directly behind the pons, and the outer membrane may be retained (brain-unskimmed) or removed (brain-skimmed). The 'whole lamb brain' is again the complete brain containing the cerebellum, cerebral hemisphere, thalamus and pons, separated behind the pons; the membrane covering may be retained or removed.

Brains, unless used immediately, should be precooked or frozen (Table 2.6). Precooking aids in removing the outer membrane and 'sets' the soft tissue to make slicing easier. Brains may also be soaked to aid in peeling. Brains are tender delicacies and are often thin-sliced and dipped in batter or flour (breaded) and deep-fat fried. They may also be broiled, sauted, braised or cooked in liquid, or broken into small pieces and scrambled with eggs. Brains are low in bind character, colour and high in collagen.

OXTAIL

Beef oxtail is available 'untrimmed' when the tail is removed from the carcass at the juncture of the second and third coccygeal veretebrae (in some countries between the sacral and coccygeal vertebrae). 'Tipped and trimmed' oxtail is trimmed to remove excess fat cover (not exceeding 6.3 mm ($\frac{1}{4}$ in)) and has three or more of the end posterior coccygeal vertebrae removed (normal range 0.8–1.0 kg (1.8–2.2 lb)).

Oxtail has a rich meaty flavour (Table 2.6) and adds texture to soups. It is usually browned and then simmered until the meat is tender and easily separated from the bone, which may be removed prior to serving. The soup stock may be combined with other soup ingredients.

STOCK

Other bones (cooked or uncooked) such as veal, lamb, pork or cracked beef bones and meat scraps can also be utilized to make soup stock. Lamb and pork bones produce distinct and strong flavours and should be used with lamb and pork recipes. The stock provides added nutrition and flavour and is very economical in cost.

The bones are usually first roasted with vegetables and onions until the meat on the bones turns brown. Fat is separated and the bones are placed in a kettle with additional vegetables, covered with hot water, simmered (2–3 hours), and skimmed. The stock is then strained and cooled. It may be stored refrigerated or frozen. This stock can be utilized in meat dishes, soups, vegetable dishes, sauces or gravies.

MEAT EXTRACT

Early work to produce a meat extract involved an alcohol extract, or a cold water extract, or a 90°C (194°F) water extract or pressing of meat (Swift de La Plata, 1957). More modern techniques to produce a meat extract may still involve pressing, or cold-water soaking, or hot-water cooking (e.g. rapid boiling of meat that is to be canned) to obtain a juice that can be concentrated into an extract. Other edible by-products may be used as starting ingredients to produce a product similar to meat extract. The yield and quality of the final meat extract are governed by: kind of raw material (sex of animal, cut of meat, post-mortem age of cut, type of tissue such as red muscle which yields higher organic solubles and lower salt levels than bones, sinews or gelatinous products), size of cut (the smaller the cut, the greater the yield), fat content of cut (lower the fat, greater the yield), length of time used in boiling (maximum solids at approximately 1 hour), number of times fresh tissue is cooked in the same soup (each extra cooking sacrifices approximately 0.16% yield), and

treatment of soup (open pan evaporation and holding time darken extract). When meat is cooked in the normal manner, it loses 40% of its weight and this shrinkage, combined with water used to rinse the cooked meat, yields approximately 2.2 l of soup per kilogram of meat (0.9 qt of soup/lb meat). Often, however, it is more economical to cook new lots of meat two, three, or even more times in the same soup, which reduces steam utilization for evaporation because the soup will have a higher concentration of solids.

The product is normally cooked by boiling 1 kg of meat in 1.4–1.6 kg boiling water (1 lb meat in 1.4–1.6 lb water) for 14–30 minutes; then, a second batch of meat is added to the soup. This process is repeated for four to six cookings; the soup is then skimmed to remove all surface fat, and it is filtered to remove coarse particles and suspended solids. It is boiled at 100°C (212°F) for 60 minutes to coagulate protein, refiltered, concentrated by vacuum evaporation (50.8–63.5 cm (20–25 in Hg)) to 50% solids, and heated (65°C (149°F)) in open pans to 16% moisture (70–150 hours). Bones are handled in a similar manner as meat tissue except: three to four parts of water to one part of bone are used, they are cooked at 88°C (190°F) for 8–9 hours, and there may be as many as 12 batches of bones cooked in each batch of soup.

Meat extract is often produced as a first or second class product composed of 16% or 19.5% moisture, 44 or 40% minimum organic soluble material, 7 or 6% creatine, 1.5% maximum water-insoluble compounds, 25% maximum ash, 4 or 5% maximum salt, 0.01% maximum saltpetre and 0.01% maximum copper. Meat extract is also produced in the solid form and is the basis of various fluid extracts and bouillon cubes, broths, 'teas', and soups.

TRIMMINGS

The 'beef outside skirt' is the thin free portion (wing) of the diaphragm muscle with the tendonous skin tissue (pleura) remaining (normal range 1.9–2.5 kg (4.2–5.5 lb)). Specifications may suggest the amount of fat and membrane trim. When used in comminuted meat products, the skirt has an average percentage of collagen, low to medium bind characteristics and low to medium pigment colour. The beef 'hanging tender' (normal range is 0.3–1.0 kg (0.7–2.2 lb)) is the thick portion (pillar) of the diaphragm muscle that is adjacent to the spinal column. Again, specifications may request the amount of fat and diaphragm remaining. The 'hanging tender' has a moderately high collagen content and very acceptable bind and colour values when used in sausage production. The 'beef weasand' is the smooth muscular lining which surrounds the oesophagus from the larynx to the first stomach (paunch) and specifications can request the degree of trim. The weasand has a high level of collagen, good bind and good colour values when used in meat emulsion-type products. These, and other beef trimmings such as 'beef cheek meat', 'beef tongue trimmings', 'beef meat from tongue trimmings', 'beef head meat' and 'beef lips' are used in sausage production.

'Beef cheek papillae on' is the muscle together with the lining of the mouth that is external to the upper and lower jaw bones from the tip of the mouth back to the parotid salivary glands at the back of the mouth. It may also include the muscle lying inside the lower jaw bone. It has none of the external lip remaining, but does contain the papillae lining of the mouth. The 'beef cheek papillae off' ('nut' or 'kernel') is

made by trimming the 'beef cheek papillae on' free of the papillae lining (Handbook of Australian Meat, 1970).

The trimmings from the head area are high in collagen, and very low to medium in bind and colour values when used as a sausage ingredient. Pork tissue such as 'pork cheek meat', 'pork snouts — lean in', 'pork snouts — lean out', 'pork head meat', 'pork skirt' and 'pork hanging tender' are also used in sausage production. Pork head has been reported to yield 67.4% of raw or 54.1% of cooked meat (Ryu and Kim, 1984). Pork snouts are high in collagen, low in bind properties and medium to low in colour values; and, the other pork products are similar to their beef counterparts.

PIGTAIL

The tail of the pig is removed between the fourth and fifth caudal vertebrae and may be mild brine-cured for 2 days or used as a jelly stock for brawn (headcheese). The reported yield from pigtail is 67.6% raw meat or 47.6% cooked meat (Ryu and Kim, 1984).

PIGS' FEET

'Pigs' feet' or 'trotters' are cleaned on the slaughter floor after scalding and while the carcass is still hot by pulling the toenails and removing the skin and hair between the toes. The feet are then scraped clean of hair and the carcass is chilled. The rear feet are cut from the ham, depending on the intended use of the ham, and for long-term country cure are separated at the middle of the hock joint, where the bone is solid, to retard bacterial entrance into the ham. For most other uses of the ham, more of the rear foot is removed. The hind foot is usually not used for human food because there is a high proportion of bone, very little muscle and the tendons are exposed during slaughter in order to hang the carcass; however, sometimes the small meaty portions are pickled and are called 'tid-bits'. The forefoot is removed at the junction of the foreshank bone and the foot bone. The foreshank is more often used for human food since it has a higher percentage of muscle (46.1% raw and 34.3% cooked meat) and a lower percentage of tendon and bone than the rear shank (Ryu and Kim, 1984). The foreshank is used for pickled pigs' feet, boned and used for sausage, or to produce a jelly stock for brawn-like products. Large feet (greater than 0.5 kg (1 lb)) are usually pickled boneless or semi-boneless and smaller feet may be split ('split foot') or prepared boneless.

Pickled pigs' feet or pork hocks (0.5–0.7 kg (1 to 1.5 lb) of lower shank portion of picnic shoulder), which may be fresh or frozen and thawed, are cured in 19 l (5 gallons) of water, 2.3 kg (5 lb) of salt, 45 g (1.6 oz) of sodium nitrite per 45.4 kg (100 lb) of feet or hocks. The pickle and tissue are heated to 93°C (200°F), the heat is turned off, the product covered and the tissue allowed to cure 18 hours in the warmed pickle. Some processors use a cold cure (40°F, 4°C) for 7–14 days. The product is then reheated to 82°C (180°F) and water cooked (some processors use vinegar-acidulated water) until the meat is tender, hot showered to remove fat, and cold-water chilled. The feet or hocks are then boned and placed in a 35-grain vinegar for 18 hours. The product is packed in jars which are filled with a 45–55-grain vinegar containing 4.5 kg (10 lb) of salt, 142 g (5 oz) of ascorbic acid, and spices and condiments to taste, per

378 l (100 gallons) of vinegar. The product is usually held for 2 weeks at 13–16°C (55–60°F) for continued pickling and absorbs 20–25% of the pickle liquid. Pickled pigs' feet must have a pH of 4.5 or below in order to be considered a shelf-stable item. They are then ready for retail distribution.

JELLIED PRODUCTS

Jellied products such as headcheese (brawn), souse and scrapple use high collagen meat sources such as pork skins and head trimmings or gelatin. Headcheese (brawn, souse) is often made from pork tongues, hearts, cheeks, ears and snouts which are cured for one week. Pork skin gelatin may be used as the binding agent and sometimes non-fat dry milk is also added. The product is seasoned, hot-water cooked (96°C (205°F)) for 2.5 hours, meat cubed, pork skins ground, mixed, stuffed into casings (beef cap-ends, pork stomach or artificial casings), cooked in 82°C (180°F) water to an internal temperature of 77°C (170°F), then cold-water chilled and placed in a 1°C (34°F) cooler for the final chill. Sometimes the product is cold (27°C) (80°F) smoked or washed in 45-grain vinegar before shipping (to retard mould growth). The product is highly perishable but may also be canned.

HAGGIS

Haggis-type products are made from hearts, lungs and livers of calves and sheep with oatmeal added, and are heavily seasoned and cooked in a sheep's stomach.

INTESTINES

Pork large intestines and stomach are collected at slaughter and are immediately thoroughly cleaned. They should be well-cooked, often with sauce, and are served as chitlings. In some countries a small portion (0.5 m (20 in)) of the small intestine of the beef animal is also used as chitlings. The intestines and other parts of the digestive tract of cattle, pigs or sheep are used as sausage casings and this use will be discussed in later chapters.

TESTICLES

'Bull testes' are the complete gland with the epididymis removed. A bull's testicle averages 0.2–0.3 kg (7–12 oz), a ram's averages 0.2–0.3 kg (6–10 oz) and a boar's averages 127 g (5 oz). Pear-shaped lamb testicles (from 2–3 month-old rams) and elongated oval calf fries or testicles (mountain oysters) are often thin-sliced, dipped in batter or flour (breaded), and deep-fat fried.

PORK SKINS

Pork skins are utilized as a binding substance for jellied products, for production of gelatin, to prepare a popped snack item or as a pre-emulsion for sausage production. Tanned pigskins are discussed in the chapter describing leather manufacturing. Popped pork rinds (bacon skins, 'skeens') are pork-skin snack foods that have been

processed so that they puff or expand to much larger than their original volume. The flavour of this high-collagen protein product is bland (it may be altered with seasoning); the texture is crisp, and the product is less hygroscopic than most puffed snack items. The raw material to produce popped pork rinds is green belly skins, green back-fat skins, green ham skins, and cured and smoked bacon skins, which are usually removed from the pork wholesale cut using a stationary blade held above a rotary burred drum. This produces skins with as little as 6 mm ($\frac{1}{4}$ in) of adhering fat, depending usually on the value of the skins and/or fat. Some processors (Matz, 1976) dip the skins (for 30 seconds) in a hot 100°C (212°F) brine composed of 5.9 kg (13 lbs) of dextrose, 5.7 kg (12.5 lb) of sucrose, and 34 kg (75 lbs) of salt per 378 l (100 gallons) of water. The pork rinds are then drained, cooled, and cut into appropriate-size squares (1.3–2.5 cm ($\frac{1}{2}$–1 in) square) for the retail market. The next step is rendering, where the skins are heated (110 to 116°C (230–240°F) for 4 hours) in prime steam-lard with violent agitation. After heating, the pellets are allowed to cool and drain and are then placed in a wholesale package. In this state they can be stored up to 6 months in an unrefrigerated condition. The retail distributor may dip the skins (Anderson and Smith, 1958) for 15 seconds in an acetic acid solution (to increase the percentage that will puff) or vinegar but usually just puffs the product in 204–218°C (400–425°F) oil and coats the surface with salt and seasonings. This puffed product will have a 3–8 week unrefrigerated shelf-life. A typical analysis (Matz, 1976) would be 99% total solids, 57% protein, 34% fat, 5% carbohydrate and 4% ash.

Pork rinds that will be used in a sausage emulsion-type product are handled in three different ways (Wilson *et al.*, 1981). The rind is removed from the carcass with as little adhering fat as possible, cooked in boiling water for 1.5 hours, or more quickly in a retort under pressure, chilled and minced (20.7% protein, 28.9% fat). The hot-cooked pork rind can also be incorporated into a pre-emulsion, which contains pork fat (50% pork rind and fat), water (44%) and an emulsifying or stabilizing agent (6%) such as soya protein isolate or sodium caseinate. This product is more heat stable than cooked rind and the pre-emulsion may be used hot when prepared, or may be chilled for later use. Both of these products are added at the mixing or chopping stage in the manufacturing of sausage, and both have some adverse effect on the texture of the product. Because these products are perishable and inconvenient to handle, a market has also developed for dried (5% moisture, 10–15% fat) rind in the granular form. It is convenient to store and rehydrates readily.

BLOOD

Blood is used in many countries as a source of human food, usually in sausages. The more complicated uses and nutritional values will be discussed in greater detail in a later chapter, but the making of blood sausage is fairly straightforward.

A hollow knife connected to a collection tube (Fig. 2.1) is used to obtain the blood in as sanitary a fashion as possible. An anti-coagulant may be added (Fig. 2.2) or defibrinated, cured beef blood may be produced by adding and stirring 57 g (2 oz) of salt and 7 g ($\frac{1}{4}$ oz) of sodium nitrate into each 3.8 l (1 gallon) of beef blood. The red beef blood is allowed to cure at 1°C (34°F) for 2 days with occasional stirring. The blood is strained and an emulsion is formed when the cured beef blood is mixed with

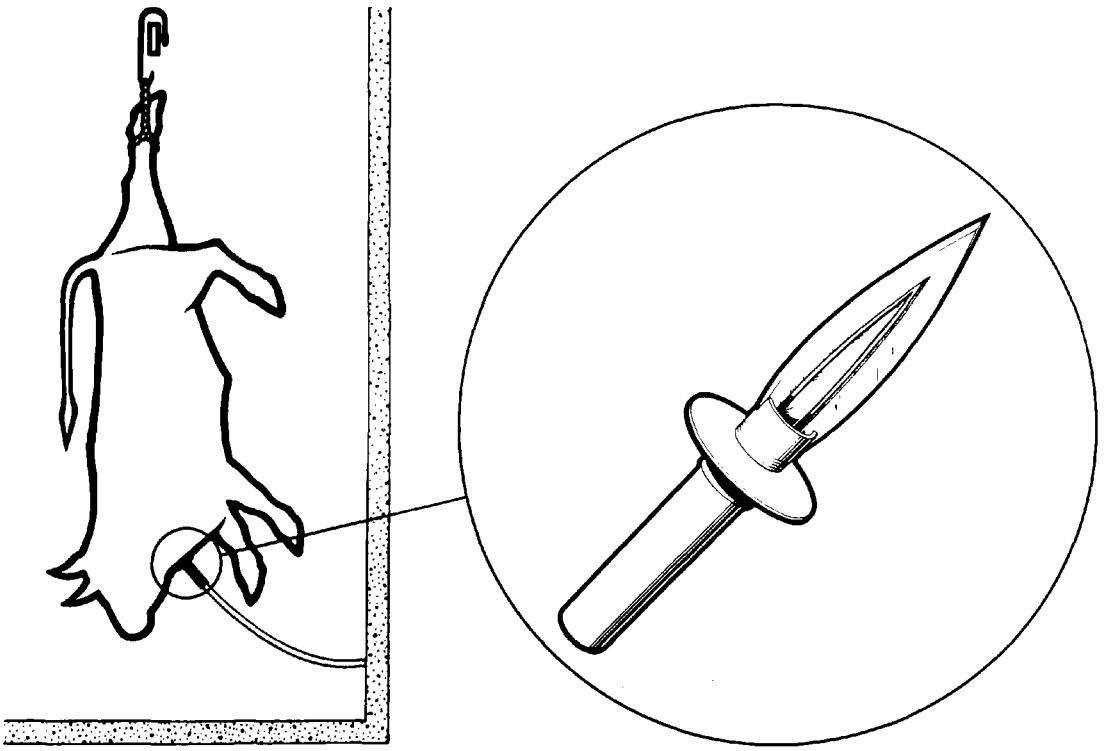


Fig. 2.1 — Hollow knife for blood collection. From Filstrup (1976).

chopped, cooked, ground and defatted pigskins. This emulsion, and other meat tissues such as cured pork tongues, cured pork jowls, cured pork snouts, cured backfat and cured shank meat, are mixed with curing and seasoning ingredients. The mixture is stuffed into beef bungs or moulds and water-cooked at 82–93°C (180–200°F) until an internal temperature of 77°C (170°F) is reached (approximately 3–3.5 hours). The blood sausage is chilled in cold water for 2 hours and finally chilled in a cooler at 2°C (36°F). The beef bung-stuffed product is normally cold smoked (27°C (80°F)) and then rechilled (Table 2.10).

SPLEEN

The spleen is a specially-designed lymphatic organ, contained in the abdomen and attached to the rumen but not part of the digestive system. All loose tissue is removed. In a beef animal of market weight, the spleen will weigh 0.9–1.4 kg (2–3 lb), is bluish in colour and is an elongated oval shape (51 × 15 cm (20 × 6 in)). In the pig it is elongated (28 × 5 cm (11 × 2 in)) and tongue shaped, triangular in cross-section, weighs an average of 170 g (6 oz) and is reddish in colour. In sheep it is oyster shaped (8 × 10 cm (3 × 4 in)), reddish brown in colour and weighs 57–85 g or 2–3 oz (Wilson, 1968).

Spleen may be fried, used in pie or as melt, used as flavouring or used in blood preparations or in blood sausages. Spleen is dark in colour and has poor binding ability. It is also high in collagen, which gives sausage a gristle-like texture. The collagen can be removed by passing the spleen through a mechanical deboner with

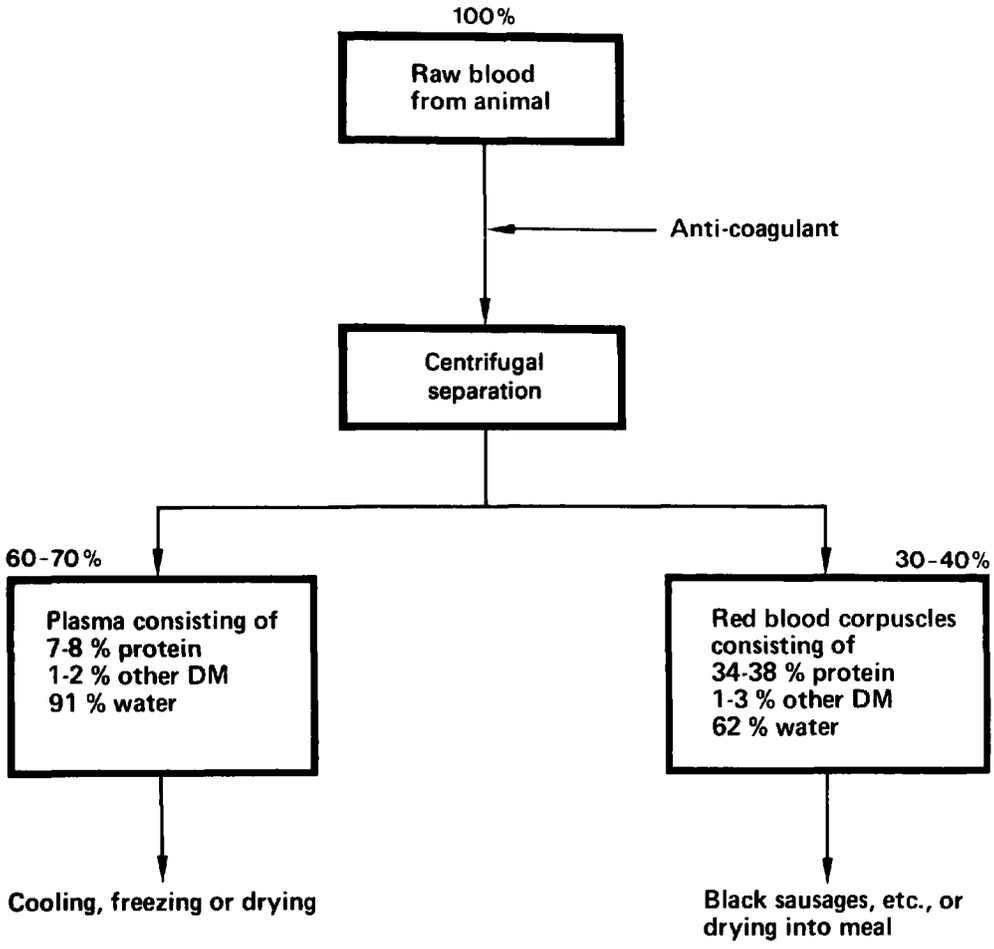


Fig. 2.2 — Processing of blood for human consumption. From Filstrup (1976).

a desinewing head. When the collagen-removed spleen was used (Bittel *et al.*, 1981) in a comminuted meat product, the colour was darker, firmness was decreased, binding was lowered and the overall product acceptance was lowered, but the greatest decrease in acceptance was reported in products containing between 10 and 15% spleen. A consumer panel considered all (tested up to 15%) the products acceptable but those containing added spleen had a spicy, more intense flavour and were softer and somewhat similar to liver sausage in texure.

POULTRY GIBLETS

The heart, liver and gizzard are removed from the remaining viscera on the slaughter floor (Table 2.1). The gall bladder is cut and pulled from the liver, and the pericardial sac and arteries are cut from the heart. The gizzard is removed by cutting it in front of the proventriculus and then severing the entering and exiting tracts. The gizzard is then split, emptied and washed, and the lining removed with a gizzard peeler. The giblets are normally wrapped in 23 × 30 cm (9 × 12 in) sheets of parchment paper, or placed in parchment bags or film, and inserted into the poultry body cavity. The wet weight of the paper should not exceed 41 kg (90 lb) per ream and the moisture

absorbed should not exceed 200% of the dry weight of the paper. The giblets are easier to place in a warm carcass, but if the carcass is chilled by a tumbling action they are then placed in the cold carcass, which increases the shelf-life of the giblets (Mountney, 1966). Giblets may also be wraped in parchment paper and frozen inside frozen birds. Giblets (may also include the neck) may be washed, salted, wrapped in aluminium foil and cooked (Table 2.6) with the poultry carcass or may be simmered in salted water until tender. The giblets can then be ground and added to crumbled bread, cornbread or cooked rice to produce stuffing. Milk and cooking broth may be added to the ground giblets to form gravy. Poultry livers are often flavoured with bacon by frying them together for approximately 10 minutes.

REFERENCES

American Meat Institute (1984) *Meat facts.* Washington, American Meat Institute.

Anderson, M. G. and Smith, C. F. (1958) *Method of puffing bacon rinds.* U.S. Pat. 2855309, Oct. 7.

Anon. (1976) *The nutritive value of meat and other protective foods.* Chicago, The National Live Stock and Meat Board.

Bijker, P. G. H. (1981) *Hygienic aspects of edible offals.* Univesity of Utrecht, The Netherlands, Doctoral Thesis.

Bischoff, J. (1985) *The dollar's current strength undermines the competitive edge held by U.S. variety meats. Meat Industry* **31**(5) 52.

Bittel, R. J., Graham, P. P., Young, R. W. and Bovard, K. P. (1981) *Mechanically separated spleen: its composition and protein efficiency ratio. J. Food Sci.* **46** 336.

Block, B. (1977) *The meat board meat book.* New York, McGraw-Hill.

Filstrup (1976) *Handbook for the meat by-products industry.* Alfa-Laval, Stockholm, Sweden.

Gerrard, F. and Mallion, F. J. (1977) *The complete book of meat.* London, Virtue Press.

Handbook of Australian Meat (1970) *Handbook of Australian meat, offals, fancy meats.* Section 7, Sydney, Australian Meat Board.

Hanna, M. O., Smith, G. C., Savell, J. W., McKeith, F. K. and Vanderzart, C. (1982) Microbial flora of livers, kidneys and hearts from beef, pork and lamb. J. Food Protection **45** 63.

Kiernat, B. H., Johnson, J. A. and Siedler, A. J. (1964) *A summary of the nutrient content of meat.* Bulletin No. 47. Washington, American Meat Institute Foundation.

Komarik, S. L., Tressler, D. K. and Long, L. (1974) *Food products formulary, Vol. 1, Meat, poultry, fish, shellfish.* Westport, Connecticut, AVI.

McLean, B. B. and Campbell, T. H. (1952) *Martha Logan's meat cook book.* New York, Pocket Books.

Matz, S. A. (1976) *Snack food technology.* Westport, Connecticut, AVI.

Mitsyk, V. E., Konyushenko, N. F. and Pshenichnaya, E. P. (1972) Enzymic hydrolysis of meat or offals in production of dietetic and remedial foods. *Trudy, Ukrainskii Nauchano-issledovatel'skii Institut Mayasnoi i Malochnoi Promyshlennosti*, No. 2, I, 60–63.

Mountney, G. J. (1966) *Poultry products technology*. Westport, Connecticut, AVI.
National Live Stock and Meat Board, (1974a) *Lessons on meat.* Chicago, National Live Stock and Meat Board.
National Live Stock and Meat Board, (1974b) *Recipes for variety meat.* Chicago, National Live Stock and Meat Board.
Ockerman, H. W. (1975 & 1983) *Chemistry of Meat Tissue*, 8th edn. and 10th edn. Columbia, Ohio State University.
Paul, A. A. and Southgate, D. A. T. (1978) In *The Composition of Foods*, 4th edn. McCane, R. A. and Widdowson, E. M. (eds.), London, HMSO.
Percel, P. J. (1979) *Influence of curing method, massaging and phosphate on quality, yield and chemical composition of pork liver loaf.* The Ohio State University, Columbus, MS. Thesis.
Pierson, C. J. (1982) *Influence of time and temperature of frozen storage and packaging method on functional properties and quality characteristics of beef and pork livers.* The Ohio State University, Columbus, PhD Dissertation.
Renon, P., Comi, G., Cantoni, and Persiani, G. (1980), Acidi grassi del grasso d'organd di animali domectici. *Industie Alimentari* **19**(6) 507–510.
Romans, J. R., Jones, K. W., Costello, W. J., Carlson, C. W. and Zeigler, P. T. (1985) *The meat we eat*, 12th edn. Danville, Illinois Interstate.
Ryu, B. H. and Kim, H. S. (1984) Nutritional evaluation of head, feet and tail tissue of pig. *J. of Korean Society of Food and Nutrition* **13**(2) 149–155.
Shelef, L. A. (1975) Microbial spoilage of fresh refrigerated beef liver. *J. Appl. Bacteriol.* **39** 273.
Swift de la Plata (1957) *Accumulated information on meat extract.* La Plata, Argentina, Swift de La Plata.
University of Illinois and National Livestock and Meat Board (1986). Unpublished survey by By-Products, Chicago.
USDA (1963) *Composition of foods, agricultural handbook no. 8.* Washington, Agricultural Research Service.
USDA (1980) *Composition of foods, sausage and luncheon meats, raw–processed–prepared, agriculture handbook 8–7.* Washington, Science and Education Administration.
U.S. Meat Export Federation (no date) *Variety meat from the U.S.A. — a buyers guide*, 2nd edn. Denver, Colorado.
Wilson, A. (1986) *Practical meat inspection.* Oxford, England, Blackwell Scientific Publications.
Wilson, N. R. P., Dyett, E. J., Hughes, R. B. and Jones, C. R. V. (1981) *Meat and meat products, factors affecting quality control.* London, Applied Science.

3

Rendering

So-called animal by-products used by the renderers and consisting of excess fat, bones, hoofs, and offal have long been useful to man. Tallow was probably used prehistorically for softening and waterproofing garments and for lighting. Although soap-making began many thousands of years ago, tallow candles were in widespread use by the common people before tallow-based soap. Towards the latter part of the nineteenth century an industry evolved which transformed by-products into fertilizer.

Soap may have been made by the Babylonians as early as 2800 B.C. Other records indicate the Phoenicians were making soap in 600 B.C. (Encyclopedia Americana, 1985). There is evidence that soap-making was known to the Romans. Notwithstanding an apparent general knowledge of soap, its use was limited to cleaning hair and body until the mid 1800s. Soap was apparently a fine luxury, for even Queen Elizabeth I in the later sixteenth century was reported to have indulged in a hot bath with soap but once a month. There was also a stiff tax on soap in England from the twelfth to the nineteenth century (Burnham, 1978).

Before soap was widely used, candles were the main product made from tallow. This was true until the latter part of the nineteenth century (Burnham, 1978). Even the common tallow candle was considered somewhat of a luxury. It was portable, unlike the fireplace, and it did provide a little artificial illumination. Candles were made in one of three ways: dipping, moulding or ladling melted oil or wax over the wick. The candle maker was a tradesman, but many candles were made at home.

The development of an industry to utilize by-products for fertilizer came during the nineteenth century (Dainty, 1981). The highly perishable and evil-smellling by-products of the slaughterhouses — entrails, heads, hoofs — were considered waste until about the 1850s. Some meat packers would simply bury the material adjacent to their plants. Some enterprising meat men soon discovered that they could transform these materials into farm fertilizer and realize a fair profit from the operation. In fact, when these raw products were available at no cost, which apparently was the usual situation, there was more profit from processing them than the profit from the meat-packing business itself (Dainty, 1981). Proteinaceous by-products would yield nitrogen fertilizer, whereas bone produced phosphate fertilizer.

The rendering industry today produces hundreds of useful products which can be

broadly classified as edible and inedible oils, chemicals, meat meals, and bone meals. These valuable products are produced from animal by-products (viscera, bones, trimmings, dead stock, feathers) that otherwise would, for the most part, be considered waste. Fig. 3.1 gives the composition of various raw materials. The

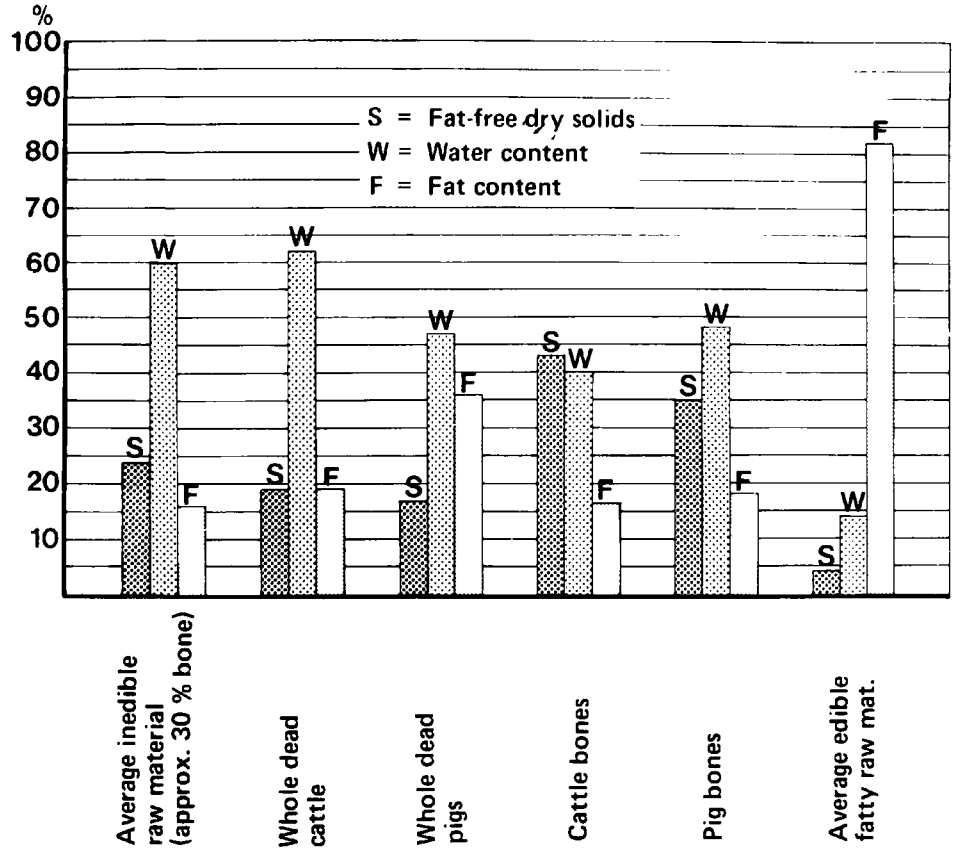


Fig. 3.1 — Composition of various raw materials. From Filstrup (1976).

amount of by-product recycled into useful products is very large: so large it is difficult to comprehend. As examples, consider that about 30 billion (30×10^9) pounds of inedible animal by-product is produced in the United States each year (Burnham, 1978). This is roughly equivalent to the household waste that would be generated by a city of 1 million people in 6000 years. Thirty to sixty per cent of the hundreds of thousands of cattle, hogs (pigs), sheep and poultry slaughtered daily in the U.S. is recycled by the renderer. The handling and processing of such large volumes of waste has led to the development of sophisticated equipment and processes which will be discussed later in this chapter.

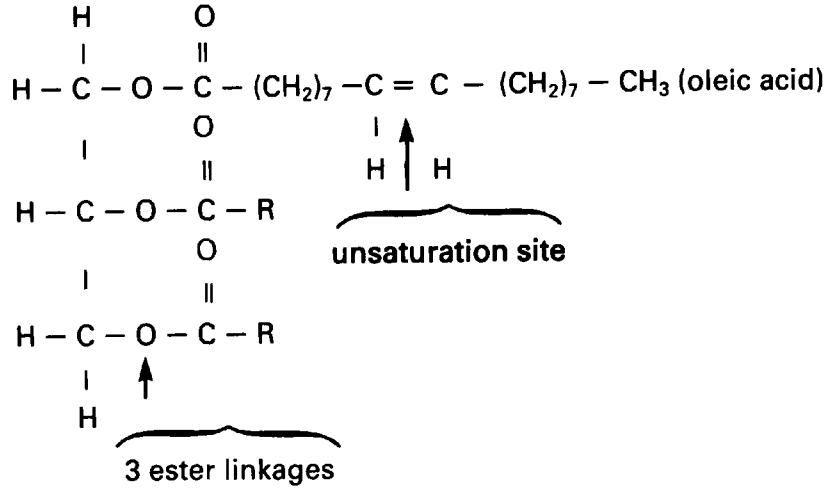
PRODUCTS OF RENDERING

Tallow/lard

Generally tallow is referred to as the rendered fat of cattle and sheep. Lard is the rendered fat of the hog. However, a more accurate definition is to refer to tallow as animal fat with a titre of greater than 40°C (104°F) (Austin, 1949). Lard or grease has

a lower titre. Titre refers to the softness or hardness of animal fats expressed as the temperature at which the fatty acids of the given fat solidify.

Animal fats are triglycerides; a molecule of glycerol ($C_3O_3H_8$) bonded to three fatty acids with ester linkages as follows:



The degree of unsaturation (double bonding) and fatty-acid chain length may vary. The unique characteristics of tallow are due to this chemical configuration. For example, this is the reason that tallow can be so easily split into essential and valuable chemicals including fatty acids and glycerol, and, after additional processing, soaps, cosmetics, rubber, plastics, and anti-spalling (chipping) agents for concrete and explosives. Unfortunately, the unique chemical properties of tallow include a propensity to biological and chemical decay including rancidity by oxidation, deterioration by hydrolysis and browning by overheating.

The quality of animal fat both edible and inedible is judged by titre, free fatty acid (FFA), FAC colour (standard set up by the Fat Analysis Committee of the American Oil Chemists Society) or Lovibond colour, moisture impurities (insoluble) and unsaponifable matter (MIU). Jones (1984) outlines what each of the tests for tallow quality entails:

Titre

This refers to the softness or hardness of a tallow or the temperature at which fats solidify. Fat of different species of animals such as cattle, sheep (higher) and pigs (lower) have different titres. Within each particular animal, fats have different titres depending on location. For example, the titre of fat trimmed from the loin is different from kidney fat (higher).

Type of feed can affect the titre. For example, pigs fed on peanuts produce tallow with a different titre from that of those fed on corn (higher). Also, the well-being of the animal can affect the titre. An animal in good physical condition will have fats of a higher titre than one which is emaciated.

Solidification points of animal fats, or titres, are as follows:

Pig	36–40°C (96.8–104°F)
Cattle	42–45°C (107.6–113°F)
Sheep	44–48°C (111.2–118.4°F)

The presence of bone oil can affect the titre of a fat. The way in which tallow is processed does not change the titre.

The American Fats and Oils Association (AFOA) rule for variance of specification is as follows:

> Titre: The seller shall allow the buyer 0.2% of contract price for each 0.1% titre deficiency, fractions in proportion. The buyer may reject the tender when titre deficiency exceeds 0.5°C (0.9°F).

Free fatty acid (FFA)

It is usual to express FFA as percentage free oleic acid of total sample weight. The amount of FFA in a tallow is an indication of the degree of spoilage which has taken place. To keep FFA to a minimum, attention must be paid to the following:

(1) Clean material.
(2) Clean equipment.
(3) Keeping raw material as dry and cool as possible. Either store at below 20°C (68°F) or conversely increase heat to 65°C (149°F), at which temperature bacteria and enzymes are inactivated. If temperature control is not possible, it may be necessary to reduce the pH to 3.5–4.0 by spraying with an acid.
(4) Keeping raw material whole for as long as possible. Prebreaking too early allows for additional exposed surfaces, with associated growth of bacteria and enzymic action.
(5) Speedy handling.
(6) Controlled pressures and temperatures in rendering and storage.
(7) Any other measures found necessary depending upon circumstances.

AFOA specifications require the FFA to be not more than 2%. Penalties under AFOA rules are as follows: (a) Where a contract specifies an FFA maximum of less than 10%, the seller shall allow the buyer 2% of contract price for each 1% of excess FFA, fractions in proportion. However, the buyer may reject the tender if the FFA exceeds the contractual limit by more than 2.0% FFA. (b) Where the contract specifies an FFA maximum of 10% or more, the seller shall allow the buyer 1% of contract price for each 1% excess FFA, fractions in proportion; however, the buyer may reject the tender if the FFA exceeds the contractual limit by more than 5.0% FFA.

Fat Analysis Committee (FAC) Colour†

Fats can vary in colour. They can be almost white to yellow. They can also be green, brown, or red. Colour can be affected by breed, feed, age, condition and location of livestock.

Green colour in tallow comes from contact with gut contents, i.e. the chlorophyll in digested plant. In dry rendering, overheating will give tallow a reddish appearance, and the presence of blood will give tallow a brownish discoloration.

Assuming the tallow is a true and representative sample of the consignment, and

† Lovibond colour may also be used. The Lovibond colour system uses a set of glass standards to match the colour to the product. The fats are graded lower as colour intensity increases.

there has been no adulteration, a colour reading may be obtained by placing a melted and filtered sample between coloured discs and gaining a reading by comparison. If a tallow has a reading between 11 and 11AS, the official colour reading would be 11A. Measures to safeguard colour are:

(1) Material to be processed should be fresh, clean, and free of contamination, and
(2) Blood and or gut contents should be kept out of cookers, and control temperatures and pressures.

Penalties under AFOA rules are as follows:

FAC colour: The seller shall allow the buyer 2% of contract price should the FAC colour be one shade darker than the FAC colour specified in the contract. However, if the FAC colour is darker by two shades or more, the buyer may reject the tender.

Moisture, impurities (insoluble) and unsaponifiable matter (MIU)

Moisture

Pure fat is virtually free of moisture. However, moisture is a necessary agent in the cleaning of offal, and raw material in the cleaning process absorbs water if allowed to stand for lengthy periods.

Water in tallow is undesirable because it acts as a medium for the growth of bacteria and the action of fat-splitting enzymes. If bacteria are injected into dry fat, most will perish on account of lack of moisture.

Moisture is expressed as parts per centum (parts per hundred by weight). Levels around 0.2% are desired.

Points to watch:

(1) Allow offals to drain if possible.
(2) Keep raw material as cool as possible, particularly where water is present. Implement temperature control as necessary.
(3) Avoid the ineffective use of water in the settling process.
(4) Drain off any water from settling and storage vessels. Water may be introduced during production or from condensation.

Impurities (insoluble)

Raw fat may contain 90–95% of fatty material. The balance is tissue. This tissue, together with other foreign materials such as protein fines, finely ground bone, hair and manure, constitutes the main impurity of tallow. Other impurities may be in the form of colloidal fines from the gut contents, which may not be removed by settling or centrifuging. These insoluble impurities are visible and the processor has the ability to remove them by more sophisticated processes of filtration, but it is those which have become soluble in the fat which may prove troublesome.

Impurities (oil soluble)

These soluble impurities include trace elements such as copper, tin (from brass) and zinc. Also included may be polyethylene, which melts in the cooking process and dissolves in the tallow. Dissolved polyethylene normally settles and burns onto the

coils, particularly if steam is the heating agent, and forms an insulating barrier. Polyethylene in inedible grades of tallow has become so prevalent that standards had to be set. The maximum is 50 parts per million. If polyethylene is present in tallow to be used for soap manufacture, the polyethylene shows up as black specks in the soap in the settling and filtration processes. The dissolved polyethylene does not settle or filter out.

Necessary measures to minimize oil-soluble contamination:

(1) Clean material.
(2) Proper settling and filtration.
(3) No injurious metals to be used in pipes and valves such as brass, copper and zinc.
(4) Supervision of raw material handling to prevent entry of materials such as polyethylene and other contaminants.
(5) The use of filter aids may be desirable.

Unsaponifiable matter

Saponification refers to hydrolysis of an ester using an alkali, i.e. ester linkages are broken yielding soap and glycerol ($C_3O_3H_8$). Soap is the salts (usually sodium salts) of the longer chain fatty acids such as oleic acid, $C_{17}H_{33}COONa$.

Unsaponifiable matter is the fatty material in a tallow which cannot be converted into a soap by the use of an alkali (i.e. no fatty acids are released by alkali treatment). Small quantities occur naturally in a fat. Cholesterol is one naturally occurring unsaponifiable fat. It is unsaponifiable material of a mineral source, such as lubricating oils and greases from pumps and machinery, which create the greatest problems and are regarded as a direct contaminant by the soap manufacturer. Substances forming unsaponifiable matter can impart objectionable odours, as well as downgrading a tallow.

Safeguards:

(1) Ensure there are no leaking glands, packings etc. on equipment, to allow greases and oils to contact the fatty material.
(2) Advise maintenance personnel of the dangers of oils and greases entering tallow storage containers.

The AFOA ruling is as follows:

> The seller shall allow the buyer 1% of contract price for each 1% of excess MIU, fractions in proportion; however, the buyer may reject the tender should the MIU exceed 2% when the contractual limit is 1% and 4%. No premium will be due to the seller for analytical results below the contractual limits.

Bleachability

The bleach test is a colour test using an activated clay and a Lovibond tintometer. It is normal to use the red readings only because there is a direct relationship between red and yellow readings. Extremes of temperature will fix colour in tallow and the bleach test is a good indication of the temperatures and handling condition to which a tallow has been subjected.

The cleaner the raw material and the lower the temperatures and pressures used, the lighter will be the bleach.

Soap manufacturers bleach all tallows prior to any recolouring. The importance of bleach readings signifies the extent of bleaching required and costs incurred.

For good bleaches, ensure the following:

(1) Clean, fresh material, free of contamination.
(2) Controlled low temperatures and pressures.

As per specification, buyers would be looking for a tallow with a bleach not exceeding 0.5R.

Penalties under the AFOA for not meeting specifications are as follows:

> The seller shall allow the buyer 2% of contract price for each excessive 0.5R, fractions in proportion. However, if colour exceeds the contractual limit by more tha 0.5R, the buyer may reject the tender.

Under AFOA rules, special penalty conditions apply to top-white tallow, beef-packer tallow and edible tallow.

Buyers accept these specifications as a guide to the quality of the product they are buying. The specifications all relate to the stability of the tallow. The stability denotes the length of time the tallow may be stored without marked deterioration.

Other tests may be conducted by buyers to ascertain properties of purchased tallow and include:

(1) Saponification number or iodine value,
(2) peroxide value,
(c) smoke point.

To identify the types of fats and oils used in tallow productions, the saponification number of iodine value is measured. The saponification number indicates the average length of fatty acid chains. The iodine number indicates the degree of unsaturation. The iodine value is low for animal fats and high for vegetable oils. The higher the iodine value, i.e. the more carbon double bonds, the lower becomes the melting point. In this manner, the presence of pig fats would be detected in a tallow allegedly derived from beef sources.

The peroxide test is used to determine the rancidity of a tallow. If the peroxide value is low, this normally suggests that the tallow has not become rancid, and will have good stability. Fresh fats have a peroxide value of 1–2, whereas rancid fats have a peroxide value of 15–20. Rancidity is caused by oxidation and hydrolysis.

One way to reduce oxidation of tallow when pumping to storage is to minimize air incorporation and foaming by allowing the tallow to flow down the walls of the tank and not to drop from a height.

Smoke point has a direct relationship with FFA and is the temperature to which the fat may be heated before it begins to smoke.

Approximate smoke points are as follows:

A tallow with an FFA of 0.2%	225°C (437°F)
A tallow with an FFA of 1.0%	145°C (293°F)
A tallow with an FFA of 5.0%	120°C (248°F)

Table 3.1 lists the standards for tallow and grease, recognized by the industry and marketers of these products in the United States.

Table 3.1 — Trading standards for tallow and grease

	Minimum Titre[a] (°C) (°F)	Maximum FFA[b] (%)	MIU[c] (%)	FAC Colour[d] (Score)	Lovibond Colour[e] (Score)
Tallow					
Edible	—	1.0	0.73	1	—
Fancy	41.5 (106.7)	4.0	1.0	7	10
Bleachable fancy	41.5 (106.7)	4.0	1.0	—	100
Prime	40.5 (104.9)	6.0	1.0	11B	125
Special	40.5 (104.9)	10.0	1.0	11C	180
No. 1	40.5 (104.9)	15.0	2.0	33	400
No. 2	40.0 (104)	35.0	2.0	No colour	—
Grease					
Lard	—	0.5	0.18	1	—
Rendered pork fat	—	1.0	0.80	—	10
Choice White	37.0 (98.6)	4.0	1.0	11B	100
A. White	37.0 (98.6)	6.0	1.0	15	125
B. White	36.0 (96.8)	10.0	1.0	11C	180
Yellow	36.0 (96.8)	15.0	2.0	37	400
House	37.5 (99.5)	20.0	2.0	39	—
Brown	37.5 (99.5)	50.0	2.0	No colour	—

[a]Melting temperature above 40°C (104°F)=tallow; below 40°C (104°F)=grease.
[b]Free fatty acid percentage.
[c]Moisture, impurities, and unsaponifiables.
[d]Fat Analysis Committee — standards are matched (white).
[e]Standards matched against product.
Source: Romans *et al.* (1985).

Table 3.2 illustrates the differential in value for the various grades of tallow in Australia.

The differential values will obviously change with market conditions — however, this gives an idea of the importance of properly caring for raw material and processing tallow correctly. Table 3.2 compared with Table 3.1 also indicates slightly different standards throughout the world.

Meat and bone meal

Prior to the turn of this century the solid residue remaining after animal fat had been rendered from animal by-products was called tankage. This material is high in

Table 3.2 — Differential values for the various grades of tallow

Grade	FFA (%)	FAC	Bleach ability (R)	Differential value each grade, edible worth $X.00	Uses
Edible	0.5	3.5	0.2	$X.00	Cooking margarines, cooking fats, medical preparations
Uncertified edible beef	1.0	11A	0.2–0.4	$X−$10.00	High quality toilet soaps, perfumery
Prime	1–2	11A	0.5	$X−$15 to $20	Toilet soaps
Inedible	1–2	11B-17	1	$X−$20 to $30	Laundry soaps, soap powders, detergents, industrial soaps
Feed tallow	10–20	Darker than 23	Over 2	$X−$100 to $120	Abrasive soaps, stock production, explosives, tempering of steel, leather preparation
Feed tallow	Over 20	Darker than 23	Over 2	$X−$150 to $160	Additional uses on account of oiliness, viscosity and lubricating properties
Gut range	3,4, and 5	17, 19, 21, 23	1−1.5	$X−$20 to $30	Industrial soaps

Source: Jones (1984).

nitrogen (from proteinaceous material), phosphorus and calcium (from bone) and was sold for use as fertilizer (Edwards, 1981).

As the science of nutrition developed, tankage was found to be an excellent animal feed, high in protein, calcium, phosphorus and fat (not all fat can be removed in rendering operations). Use of tankage for animal pet foods improved the value of the tankage and created a new outlet for rendered animal tissue.

The dry, defatted, high-protein material which results from rendering may vary depending on the raw materials used and on the processing technique employed. Therefore, material is designated by origin and method of processing as follows (Romans *et al.*, 1985; Wilder, 1960):

Tankage, meat-meal tankage, digester tankage, wet-rendered tankage or feeding tankage is the finely ground, dried residue from meat-animal soft-tissue by-products and dead animal-rendered products from direct steam injection (wet-rendering) systems. This material must not contain hair, hoof, horn, manure, and stomach contents except in such traces as might occur unavoidably in good factory practice. This material may be high in protein (55–60%) but may have reduced availability and low content of certain amino acids. When these products contain more than 4.4% of

phosphorus (P), they must be designated 'digester tankage with bone', 'meat and bone meal digester tankage', 'meat and bone meal tankage,' or 'feeding tankage with bone'. If the product bears a name descriptive of its kind, composition, or origin it must correspond thereto. It must be designated and sold according to its protein content. Most of the residue from packing plants is made into feeds. Product from rendering dead animals is more likely to be used as fertilizer or for other non-feed purposes.

Meat meal or meat scrap(s) are similar to tankage, but rendering is completed in steam-jacketed tanks (dry rendering). Protein quality is improved, and no dried blood is added to meat meal, as is often true for tankage. Again if phosphorus is greater than 4.4% the product must be designated either 'meat and bone meal', or 'meat and bone scrap'. The product must bear a name descriptive of origin, kind and composition.

Feather meal is composed of feathers, wet-rendered and ground to form a high-protein (80%) meal. Although very digestible, the protein lacks certain essential amino acids (see Chapter 12).

Poultry by-product meal is similar to meat scrap in composition appearance and value, but from a poultry origin.

Blood meal is dried, ground blood, high in protein especially the amino acid lysine. It is unpalatable as a feed ingredient and has low digestibility (Romans *et al.*, 1985). Some blood processing procedures such as flash-drying (atomizing into hot vacuum chamber) produce a better quality feed source.

Blood flour is dried blood, reduced to a fine powder.

Fish meal is similar to meat scraps and will vary in composition depending on the type of fish processed. Fish meal is high (60%) in good-quality protein.

Steamed bone meal or bone meal is ground, wet-rendered (steamed under pressure) or dried bones, suitable for animal feeding.

Special steamed bone meal is the dried, ground product, obtained by cooking dried bones, after the removal of grease and meat fibre, with steam under pressure in the process of obtaining gelatin or glue. It is suitable for animal feeding.

Bone meals are largely mineral with up to 15% protein. Composition may vary due to differences in processing technique and raw materials.

In common practice, much of the meat meal is sold as meat and bone meal with typical composition as shown in Table 3.3.

Saleable meat meal includes quality requirements other than those relating to composition as follows (Suter, 1984):

(1) Odour. There should be no odours of putrefaction. The predominant odour shall be that of cooked meat and tallow.
(2) Temperature. Storage temperatures should not be more than about 10°C (18°F) above ambient.
(3) Microbiological requirements. No detectable pathogenic organisms shall be present.
(4) Infestation. Must be free from infestation by insects and rodents and their residues.
(5) Protein quality. Digestibility and availability of animo acids is a critical parameter. Not more than 13% of the crude protein should be undigested by pepsin (0.2%) after 16 h at 45°C (113°F).

Table 3.3 — Typical composition of meat and bone meal

	50% meat meal	45% meat meal
Crude protein	50% min	45% min
Moisture	4–10%	4–10%
Pepsin digestible protein	Min 87% crude protein	Min 87% crude protein
Available lysine	Min 3.6% crude protein (71% avail)	Min 3.6% crude protein (71% avail)
Salt (NaCl)	1% max	1% max
Calcium	8–11%	8–11%
Phosphorus	4–5.5%	4.5–6.5%
Sieving 2 mm mesh	5% max	5% max
Untreated hair/feathers	2% max	2% max
Fat	8–11%	8–11%

Source: Suter (1984).

USES OF RENDERED MATERIAL

Inedible tallow

A major use of inedible tallow and grease (higher titre) of animal origin is as a high-energy additive to livestock and poultry feed (Table 3.4). These fats are usually

Table 3.4 — Inedible tallow and grease: supply and disposition, United States (million lb)

	1977	1978	1979	1980	1981	1982
Supply						
Stocks Jan 1	355	344	347	390	413	451
Production	6106	5815	5836	5916	6124	6026
Imports	4	3	NA	NA	NA	NA
TOTAL	6465	6162	6183	6306	6537	6477
Exports	2885	2698	2795	3254	3134	3035
Disposition						
Factory use	3180	3220	3117	2979	2985	2898
Soap	737	695	663	666	520	545
Feed	1330	1390	1239	1246	1323	1418

NA, not available.
Source: Romans *et al.* (1985).

stabilized with an approved antioxidant to prevent rancidity. Animal fats add energy to livestock, poultry and pet foods, and they also reduce the dust, improve colour and texture, enhance palatability, increase pelleting efficiency and reduce machinery wear in animal feed production (Romans *et al.*, 1985).

Industrial chemicals and synthetic oils originating from tallow, particularly fatty acids, are increasingly used. The list of products made from fatty acids includes abrasives, shaving cream, asphalt tile, candles, caulking compounds, cement additives, cleaners, cosmetics, deodorants, paints, polishes, perfumes, detergents, plastics, printing inks, synthetic rubber and water-repellent compounds. 'A' White grease may be used for making a high-grade lubricant. 'B' white grease is used to give viscosity to mineral oils. Other oils including cutting, heavy lubricating, special leather and illuminatory oil, are made from lesser grades of grease (Romans *et al.*, 1985). Relatively recently, it has been discovered that tallow components can be made into high-grade synthetic automobile oils and added to mineral oils to improve viscosity and other characteristics. It would seem that chemical uses for inedible tallow and its components will provide an increasing market share for the tallow produced. Research has developed these new markets and there is potential for other, as yet undeveloped markets, such as spraying tallow on plant leaves to reduce irrigation water requirements.

Considerable amounts of tallow are still used for soap making. The two main classes of soap are boiled soap and cold or semiboiled soap. Most soap is boiled soap, which appears on the market as hard soap (soda base). Soft soap (potash base) is a semiboiled soap (green soap) widely used in the medical area. Soft soap is more expensive than hard, partly because the glycerine remains in the soap. Glycerine is separated during hard-soap manufacture and is an important and valuable by-product.

Glycerine, purified by distillation, is widely used in the medical field and for manufacture of high explosives (nitroglycerine). Sufficient glycerine can be obtained from 45.4 kg (100 lb) of animal fat to make about 10.9 kg (24 lbs) of nitroglycerine.

Boiled soap is marketed as scented toilet soaps and soap powders. Floating soap contains minute air bubbles and a 15–20% higher moisture content than the non-floating soap. Cleanser is a mixture of soap, alkaline salts and mineral abrasives. Other soaps are formulated for specific purposes by addition of active (trisodium phosphate, soda) and inactive (tile, starch, clay) fillers, colouring and perfumes.

United States Department of Agriculture (USDA) scientists have developed and evaluated a tallow-based laundry soap that could replace conventional detergents. The tallow-based soap has a lime-soap dispersing agent (LSDA) which permits its use in either hot or cool water. France and Japan have started production of this laundry soap but it is not yet widely accepted.

Edible tallow

The edible portion of total tallow and lard production has steadily increased. Table 3.5 shows production and utilization in the USA. In 1986 the edible portion of total U.S. tallow production reached 23% (Anon., 1986)

Edible tallow and lard are used in oleomargarine (margarine), shortenings and cooking fats. Shortening and cooking fats represent a greater market share than does margarine. Many consider that tallow gives a better flavour to fried foods than do

Table 3.5 — Production and utilization of edible lard and tallow (million kg (million lb))

	Lard			Tallow		
Year	Production kg (lb)	Export kg (lb)	Domestic use kg (lb)	Production kg (lb)	Export kg (lb)	Domestic use kg (lb)
1977	438 (966)	60(132)	390 (861)	360 (795)	8 (18)	348 (768)
1978	486(1072)	44 (97)	438 (966)	418 (921)	23 (51)	391 (862)
1979	544(1200)	43 (94)	511(1126)	445 (982)	32 (70)	415 (915)
1980	526(1159)	65(144)	464(1023)	554(1222)	62(137)	451 (995)
1981	479(1057)	52(114)	433 (955)	499(1101)	43 (94)	452 (996)
1982	436 (962)	43 (95)	386 (851)	547(1206)	43 (95)	503(1110)
1983	431 (950)	25 (55)	417 (920)	589(1300)	45(100)	555(1225)

Source: Romans *et al.* (1985).

vegetable oils. However, claims that tallow causes heart disease has caused a decline in consumption. Additional new research indicate that consumption of large amounts of polyunsaturated fats may reduce the body's capability to fight off some forms of cancer (Shamberger, 1979).

Meat meal

Meat meals are used by livestock feeders as a source of high-quality protein, energy, B vitamins and minerals. Table 3.6 demonstrates the nutritional value of meat and bone meal as compared to other common animal feeds and feed supplements. Animal rations are based on cereal grains, but these are not able to completely satisfy the animal's nutritional requirement for certain essential amino acids (EAA). Addition of meat meal (10%) helps to satisfy the animal's requirements for EAAs, lysine, methionine, threonine and tryptophan. By inclusion of other protein concentrates, e.g. blood meal, fish meal and oil-seed meals, and addition of synthetic lysine and methionine, the entire EAA requirements of the animal are satisfied (Suter, 1984).

The bone content of meat meal provides calcium and phosphorus, thus helping to supply necessary minerals to the animal's diet (Table 3.7). Bone phosphorus is more readily available to the animal than some alternative sources of phosphorus.

Tallow has twice the energy density of protein and starch. But the residual fat left in meat meal makes a relatively small contribution to the energy of the ration.

Meat meal contains vitamins necessary to good animal health. In practice, synthetic vitamins are so inexpensive and readily available that animals' requirements are no longer dependent on feeds and feed supplements (Suter, 1984). However, meat meal supplies important B vitamins, particularly thiamin, as a supplement to rations.

Pet food is another important market for rendered animal protein. From 1980 to 1984 the pet-food industry in the USA grew about 8% per year (Burnham, 1985).

Table 3.6 — Amino acid profile (g/100 g protein) for animal feed and feed supplements

Amino acid	Blood meal	Meat and bone meal	Milk dried skim	Corn grain	Wheat grain	Whey dried	Soybean meal
Alanine	—	—	—	—	—	—	—
Arginine	2.8	2.02	0.40	0.04	0.09	0.06	1.47
Aspartic Acid	—	—	—	—	—	—	—
Cystine	1.12	0.30	0.17	0.01	0.02	0.04	0.31
Glutamic Acid	—	—	—	—	—	—	—
Glycine	2.72	3.34	0.07	0.04	0.11	0.04	0.96
Histidine	3.36	0.46	0.30	0.02	0.03	0.03	0.50
Hydroxyproline	—	—	—	—	—	—	—
Isoleucine	0.80	0.86	0.77	0.04	0.07	0.12	1.15
Leucine	8.23	1.57	1.11	0.10	0.11	0.19	1.56
Lysine	5.51	1.77	0.94	0.02	0.06	0.15	1.33
Methionine	0.71	0.35	0.27	0.02	0.02	0.03	0.27
Phenylalanine	4.87	0.91	0.50	0.04	0.08	0.06	1.01
Proline	—	—	—	—	—	—	—
Serine	—	—	—	—	—	—	—
Threonine	2.96	0.91	0.47	0.04	0.05	0.11	0.78
Tryptophan	0.88	0.10	0.13	0.01	0.02	0.03	0.27
Tyrosine	1.44	0.40	0.44	—	0.06	0.04	0.64
Valine	5.19	1.21	0.74	0.04	0.07	0.10	1.10
Crude Protein (%)	79.9	50.6	33.5	8.8	12.7	13.8	45.8

Source: Church (1984).

Table 3.7 — Calcium and phosphorus content of meat and bone scrap (49–50% protein)

Minerals	Range (%)	Average (%)
Ash	30–32	31
Calcium	8.0–12.0	8.1
Phosphorus	4.0–5.5	4.1

Source: Morrison (1987).

Generally, pet-food manufacturers are using less tallow, but more meat meal. Rendered animal products are used in both wet and dry pet foods. Pet foods require high-quality ingredients, which means renderers may have to segregate raw material.

Tallows, meat/bone meal and meat meal must have good colour and odours. Renderers may have to alter their normal operations for manufacturing in order to meet specific requirements of a pet-food manufacturer.

Bone

Due to its calcium content, some bone meal is fed to poultry for bone growth and to provide necessary calcium for egg shells. It is also used to add phosphorus and calcium to livestock and pet foods. Balanced mineral composition is necessary for good feed utilization. Some animals, i.e. those pregnant or lactating, require higher levels of minerals in the diet.

The mineral content of bone makes it useful as plant fertilizer. However, modern farming techniques favour fertilizer with high phosphorus and nitrogen concentrations, which bone meal does not have. Therefore, the market for ground bone as a fertilizer is a relatively small.

Animal glue, useful for wood, leather, paper, etc., is made from bones by extracting the collagen by heating in water. The water is evaporated to yield glue. Although animal glue usage decreased considerably due to synthetic adhesives, there is still a limited market (Teachman, 1981). See Chapter 5 for more details on glue.

RENDERING SYSTEMS

There are probably as many rendering systems, differing slightly from one another, as there are rendering plants. However, all these different systems can generally fit into one of four categories: (1) autoclave (wet rendering), (2) dry batch, (3) dry continuous or (4) continuous low-temperature systems.

The basic autoclave or batch wet-rendering system is shown in Fig. 3.2. The autoclave or cooker is filled with pre-ground raw material. It is then closed and steam is injected into the raw material at about 140°C (284°F), 361 KPa (58.4 psi) pressure. After treatment lasting 3–4 hours the pressure is slowly reduced to atmospheric (101 KPa (14.7 psi)). Slow pressure reduction avoids emulsification. The material in the cooker is then removed and free-flowing fat drained off. The moist cracklings or solid portion is pressed to remove additional liquid and then dried. The method of pressing may be batchwise, as with a hydraulic press, or continuous, with a screw press. Extracted liquid contains fat, water, and fines. The fat is separated out by allowing the water and fines to settle by gravity or in a centrifuge. Extracted liquid may be heated or chemically treated to enhance separation of the fat.

Dry batch systems (Fig. 3.3) employs cookers which are steam jacketed and often have a hollowed, steam-filled agitator. Material is loaded and unloaded in batches. Condensing steam in the jacket and agitator provides dry heat. No steam or hot water is added to the raw material. Material is ground to less than 2.5 cm (1 in) and batch-fed into the cooker, which is then closed. Water is removed, but the fat is not severely degraded by scorching. The steam-filled agitator improves heat transfer to the raw material such that lower temperatures can be used to liberate the fat, while completely drying the raw material in 1.5–2 hours (Burnham, 1978). Free-flowing fat is allowed to drain from the processed raw material. Remaining solids are pressed to remove residual fat.

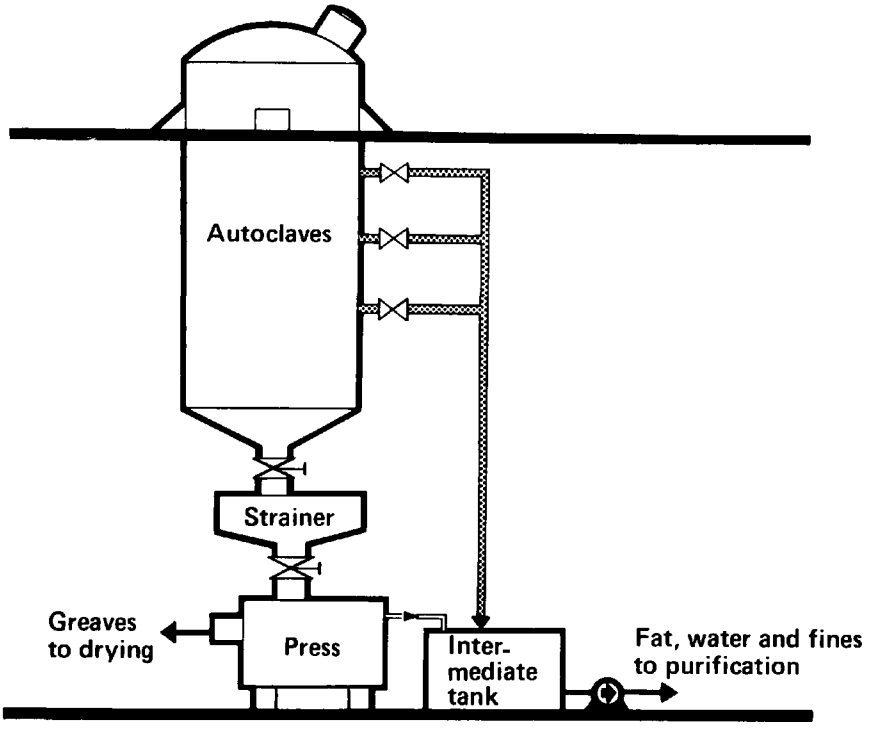


Fig. 3.2 — Wet-rendering system with autoclaves. Greaves are the pressed, cooked material. From Filstrup (1976).

The continuous dry rendering system (Fig. 3.4) is similar to a batch dry rendering system, in that moisture is driven off by dry heat; however, there is a difference in the flow of material into and out of the cooker. The flow is continuous and the raw material is treated at atmospheric pressure. The cooker is usually horizontal, steam-jacketed, and equipped with a hollowed, steam-heated agitator (see section on continuous rendering equipment). Ground, raw material enters at one end while processed material exits at the other continuously. The duration of the cooking period depends on the retention time in the cooker. This is determined by cooker volume, heat-transfer capability, and characteristics of the raw material. The cooker discharges into a percolator (a tank with a strainer or drainer screw at the bottom). The material then is removed to a press, often a screw press which can handle material continuously, or possibly a pusher centrifuge or basket centrifuge. Solids remaining after pressing are ground into meat meal.

Continuous low-temperature systems, also called mechanical dewatering systems (Fig. 3.5) have similarity to the old wet batch (autoclave) system in that the bulk of moisture is not removed by evaporation or thermal treatment. Most of the moisture in modern low-temperature systems is removed by mechanical methods made possible by the difference in density between fat, water and solids.

Raw material is minced, then passed to a low-temperature dry or wet (steam-injection) cooker, called by various manufacturers a coagulator, preheater, or melting section. The material is heated to 60–90°C (140–192°F) in a relatively short time, 10–30 minutes. Cells break, liberating the liquid tallow. Liquid tallow is

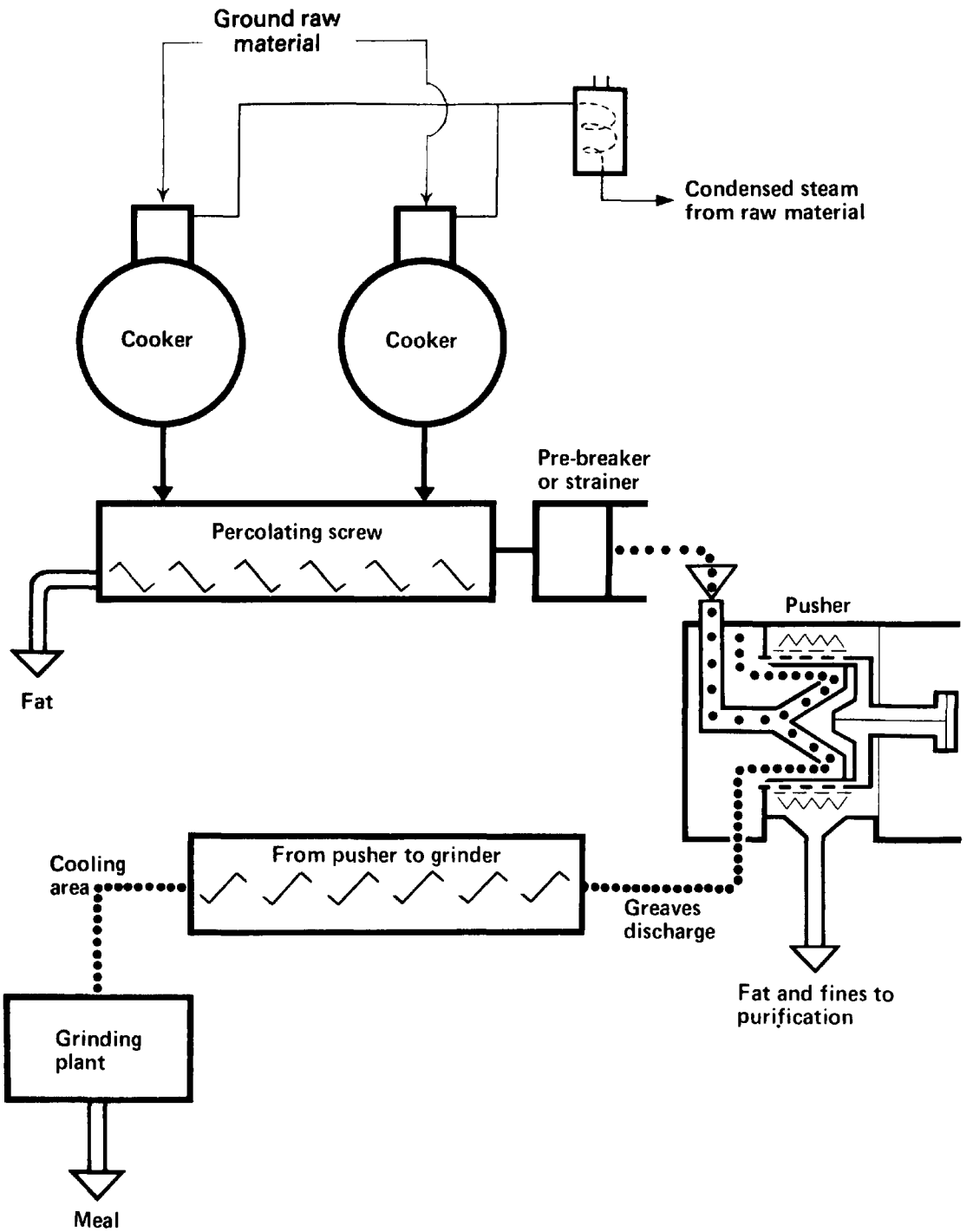


Fig. 3.3 — The conventional batch dry-rendering method. From Filstrup (1976).

pressed out in a continuous press (screw press) along with water, which will be nearly equal in volume to that in the raw material and higher if live steam-injection is used to heat the raw material. Solids are sent to a cooker/drier. The liquid mixture along with some solids (fines) is then sent to the centrifuge. Water, fat and solids may be removed in a single operation in a special centrifuge called a tricanter, or they may be removed in a multistage operation.

If the liquid mixture is sent to the evaporator it will first be screened (vibrating or self-cleaning screens work well for this) to remove solids that may plug the

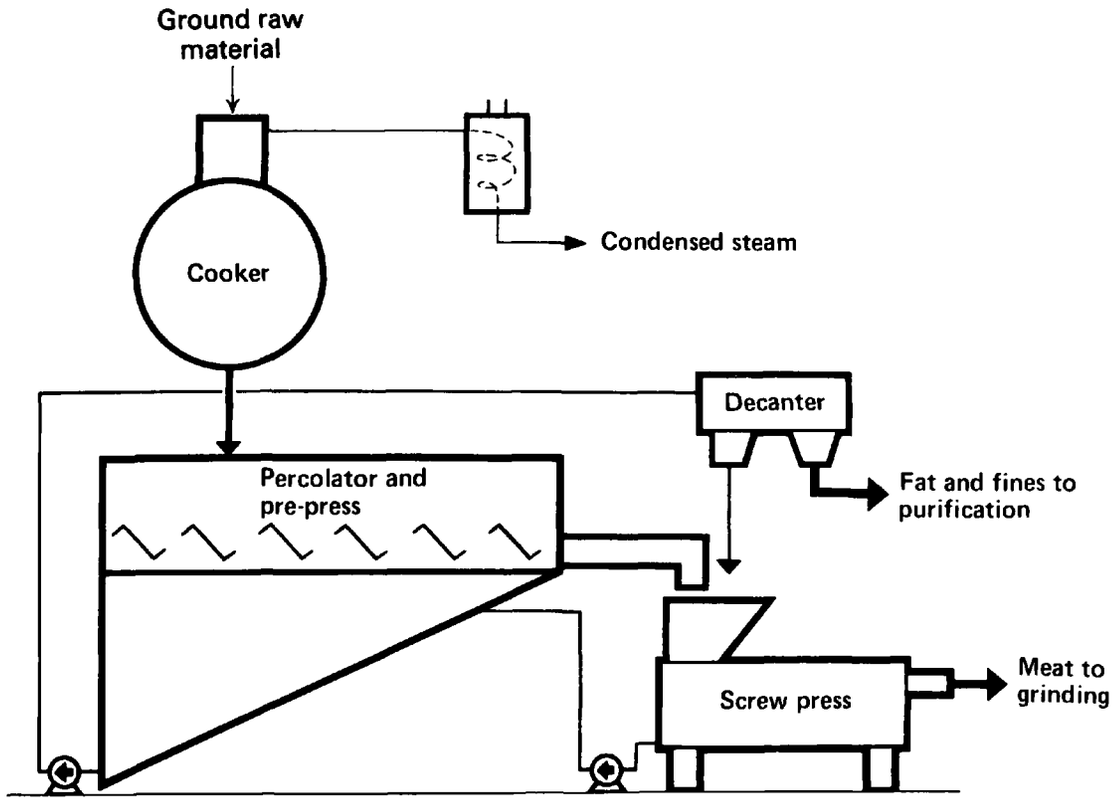


Fig. 3.4 — The continuous dry-rendering method. From Filstrup (1976).

evaporator. Screened liquid passes to the evaporator where some of the water is boiled away from the tallow under low pressure and therefore a temperature considerably lower than 100°C (212°F). The steam side of the evaporator often is supplied with waste vapours from the cooker/drier. This results in considerable energy savings as compared with releasing vapours to the environment, or condensing them and dumping into the sewer.

When the liquid mixture from the presses is sent directly to a centrifuge, most of the water will be removed mechanically, but the remaining tallow/water mixture will require 'polishing' to remove the remaining water, fines, etc. An evaporator using waste heat or live steam (steam directly from boiler) for the steam side may be used to remove remaining water. A second, 'polishing' centrifuge or filter press may be used for final clarification of the tallow.

The cooker/drier used to dry the solids is similar to the unit used in continuous dry rendering. Material, which contains about 40% of the original moisture in the raw material, passes into the cooker, where remaining moisture is driven off by heat. Live steam supplies the energy to heat the moisture and convert it to a vapour. In virtually all modern continuous low-temperature systems the heat in this vapour is recovered. The vapour may be used to provide heat for the evaporators, or to preheat raw material coming into the system, or perhaps for both purposes.

The relatively low temperatures used in modern, mechanical dewatering, rendering systems provide an opportunity to produce a high-quality tallow and reduce energy consumption as compared with heat drying of tallow. Manufacturers claim the mechanical dewatering system can remove a higher percentage of tallow from the raw product, leaving only 7–10% in the solids portion (meat and bone meal), which is several per cent lower than that often reported in dry systems.

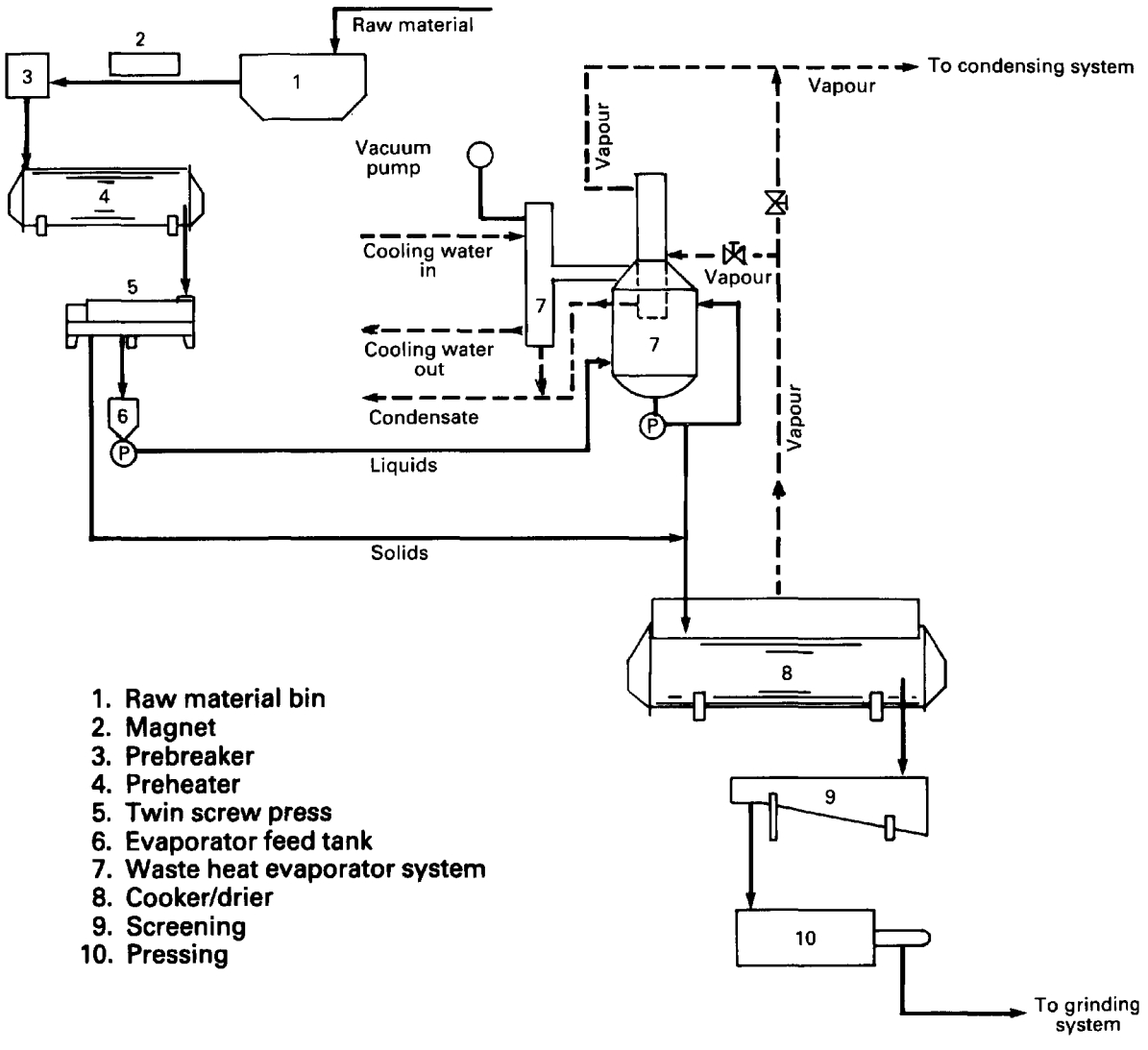


Fig. 3.5 — Continuous low-temperature rendering system. (Patented by Stord Bartz as a waste-heat dewatering rendering system.) Courtesy of Stord Bartz Company, 1986.

Continuous rendering equipment

In a continuous system, material is added and removed in a nearly steady stream. Size-reduction equipment, cookers, presses, evaporators, and centrifuges are notable among the equipment that must operate on a continuous basis. Control of material through the system is usually done by providing surge bins and variable-speed drives between one unit operation and the next.

Size reduction equipment is inherently continuous, for raw material is fed and particles removed in a constant stream. In general, size reduction is accomplished with rotating knives, devices called 'hogors' or with rotating hammer devices called 'hammer mills' or simply 'grinders'. The rotating knives on a hogor have cutting edges parallel with the surface of the rotor, are 7–10 cm (2.7–3.9 in) wide and protude only a few centimetres from the rotor they are mounted on. The rotor on a large hogor will be less than a metre in length yet require a 150 kw (200 hp) motor or

larger to operate. Such a unit would be sufficient to maintain a throughput of preground material through a medium-sized rendering plant. Throughput capacity depends on many factors, including percentage of bone and size of material coming in.

Another type of hogor, which might be called a prebreaker, contains anvils (raised rectangular solid steel teeth) in place of knives. These anvils rotate between parallel bars at the bottom of the hogor so that large material is broken up as it moves through the bars. Prebroken material will likely pass through another size reduction before entering a continuous preheater or cooker/drier.

A hammer mill (Fig. 3.6) grinder uses forces of impact and pinching action to

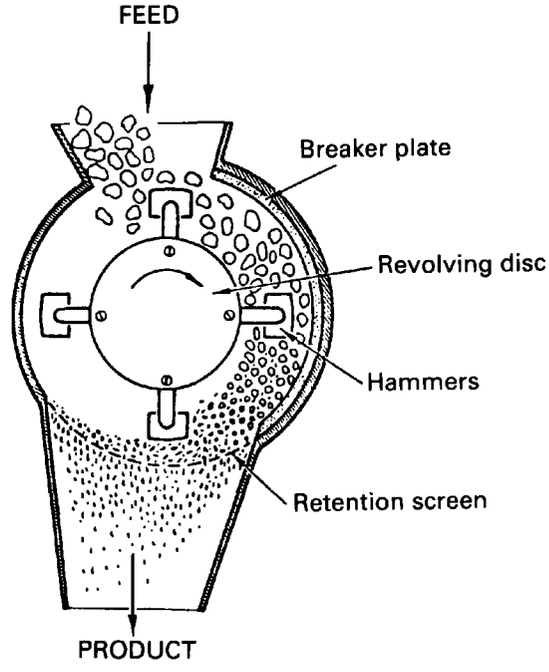


Fig. 3.6 — A hammer mill. From Brennan *et al.* (1969).

reduce the size of material and force it through the retaining screen. A high-speed rotor carries a collar bearing a number of hammers around its periphery. When the rotor turns, the hammer heads swing through a circular path inside a casing containing a toughened breaker plate. Feed passes into the action zone where the hammers impact against the material and drive it into the breaker plate and through the retention screen. The hammers may be replaced by cutters or by bars.

The continuous preheater or cooker/drier is an integral part of any continuous rendering system either wet (mechanical dewatering) or dry. A unit used for continuous cooking/drying as shown in Fig. 3.7 may also be used as a preheater for a mechanical dewatering system.

The cooker/drier is constructed as a cylinder through which the ground, raw material is conveyed by means of a rotor or agitator which also forms a type of screw conveyor. Both cylinder and agitator are steam-heated.

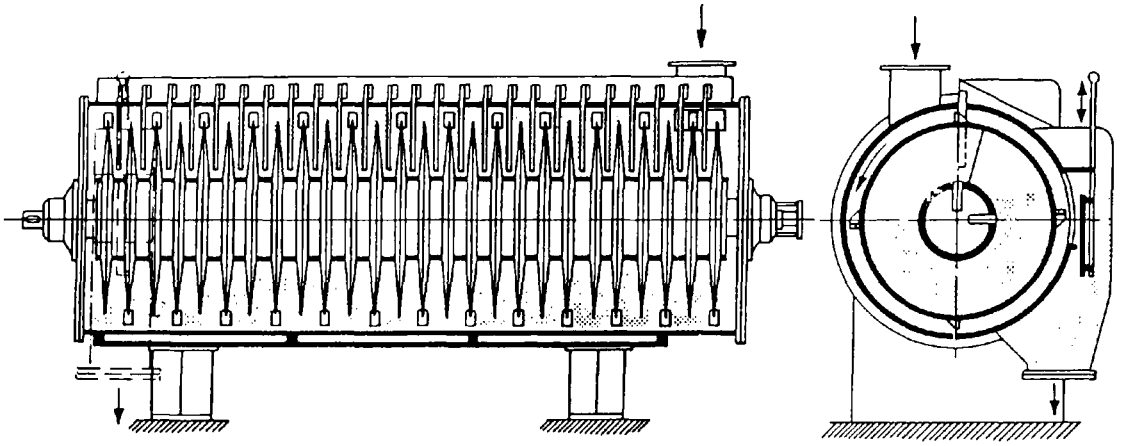


Fig. 3.7 — Continuous cooker/drier. Courtesy of Stord Bartz Company, 1986.

The steam jacket of the cylinder may be divided into sections, each section provided with devices for individual regulation of the steam supply and for securing proper condensate discharge.

The agitator or rotor consists of a shaft pipe to which hollow flights are welded. Both shaft pipe and flights are steam-heated and provided with a system for distribution of steam and drainage of condensate.

Average cook temperature and retention time are controlled by the loading rate and temperature, pressure and quantity of steam used. Loading rate is often controlled by a photoelectric device coupled to a variable-speed feed screw. Treated material may be removed by means of a control wheel. This is a paddle-wheel type of device with buckets spaced around the circumference of the wheel to pick up treated material and drop it into the drain screw (Moffat, 1984). Much of the fat and moisture will freely drain off in the drain screw as the material is being conveyed to the presses.

Continuous pressing is accomplished with a screw press, which may contain either one or two rotating elements. Fig. 3.8 is a diagram of a twin-screw press which shows how volume is reduced as material travels through the press, in this case from right to left.

Wet material to be pressed is fed into an inlet chute at the V_1 end of the press. The material fills the free space between the screw flights and the strainer plates. By rotation of the press screws, the material is, due to the decreasing cross-section, submitted to a steadily increasing pressure, which causes an efficient squeezing of the wet material. Press liquid escapes through perforated strainer plates around the screws, and is collected in a tray equipped with discharge pipe. The pressed, dewatered and defatted material is discharged axially at the end of the press and falls down onto a suitable conveying system.

The throughput and volume ratio of screw presses are determined according to the characteristics of the material to be pressed. For moist and soft materials, there is generally a quick initial compression followed by a more slowly increasing compression rate during the subsequent pressing.

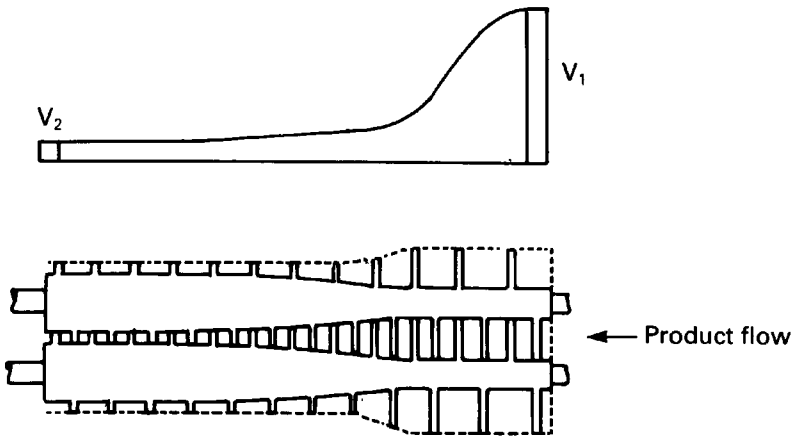


Fig. 3.8 — Diagram of twin-screw press with compression ratio volume 1 (V_1)/volume 2 (V_2). Courtesy of Stord Bartz Company, 1986.

Screw presses with a single screw work in a similar manner to double-screw presses, with a reduction of volume as material moves down the screw. Screw presses may also be equipped with a choke at the solids outlet end which has the function of holding solids back to build up pressure. This results in compaction of the solids and thus dewatering/defatting. Chokes may be hydraulically operated and automatically positioned according to main motor load.

Evaporators are used in continuous low-temperature rendering system to remove water from liquid mixtures economically. Evaporators have an advantage of operating at relatively low temperatures, which prevents scorching. Water removal by evaporation is an energy-intensive process and low-pressure evaporators are more efficient at this than open kettles or other systems operating at atmospheric pressure. At 0.5 times atmospheric pressure, water boils at 81.5°C (179°F). Evaporators can be made to operate at much lower pressures than 0.5 atmospheres, therefore 'waste' vapours from an atmospheric cooker/drier operating at just above 100°C can be used as the heat source for the evaporators.

Fig. 3.9 illustrates a single effect evaporator and a typical method of operation. Condensation of live steam or cooker/drier vapour in the steam jacket provides the heat source to drive the evaporator. Vapour produced from the liquid being evaporated is condensed by cool water sprayed into the condenser chamber. The water leaving the condenser flows through a barometric leg into an open tank. The water level in the barometric leg is higher than that in the open tank so that it pulls a vacuum within the evaporator approximately equal to 74 mm mercury (7.6 psi) vacuum per m (3.28 ft) of water in the barometric leg. A pump may be used in place of the barometric leg to maintain vacuum. The function of the vacuum pump is to remove non-condensable gases such as air from the evaporator.

Multiple-effect (stage) evaporators (Fig. 3.10) may be used, which in theory will nearly double the efficiency of evaporation with each doubling of effects, meaning twice as much liquid is evaporated per quantity of live steam or waste vapour consumed in the steam jacket. In a multiple-effect evaporator system, vapour from

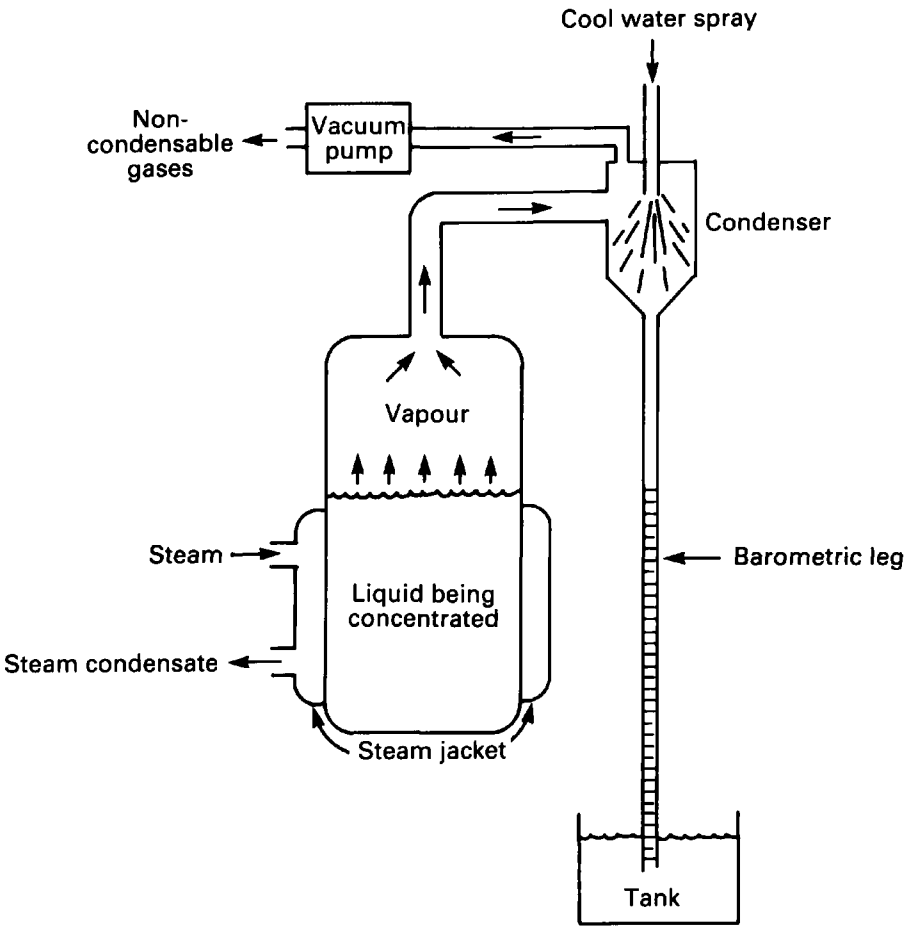


Fig. 3.9 — Simple single-effect evaporator. From Batty and Folkman (1983).

an effect is condensed in the steam jacket of a succeeding effect. This is possible because the succeeding effect will be operated at a lower pressure and thus lower temperature.

Modern evaporators require more heat-transfer surface than is provided by simply jacketing the boiling chamber. They often consist of vertical tube bundles with the heating medium on the outside of the tubes and the product boiling on the inside. Product is either moved up through the tubes (termed rising film) or downward through the tubes, when the evaporator is called a falling-film evaporator. The product is fed into these evaporators in a way and at a proper flow-rate to facilitate formation of a thin film covering the inside of the tubes. This results in very high heat-transfer coefficients and a tremendous amount of water can be boiled off within a relatively small area of equipment.

A mixture of water, tallow and fines can be mechanically separated into pure components by centrifugation. Centrifugation may be defined as a unit operation involving the separation of materials by the application of centrifugal force. So called decanters (Fig. 3.11) and disc-type high-speed centrifuges (Fig. 3.12) are used in the rendering industry.

The traditional role of decanters in meat packing/rendering is: (1) primary

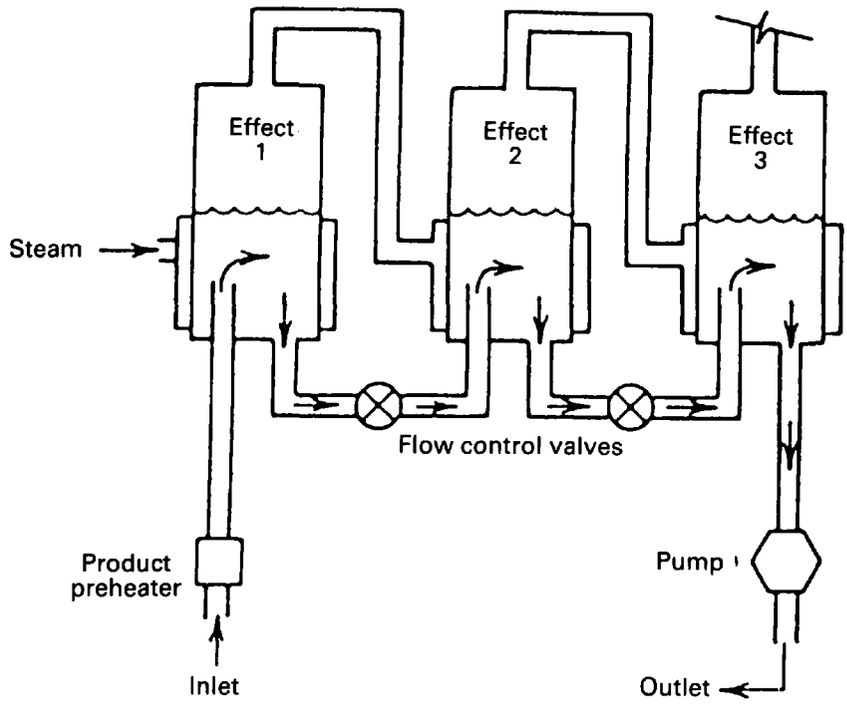


Fig. 3.10 — Multiple-effect evaporator. From Batty and Folkman (1983).

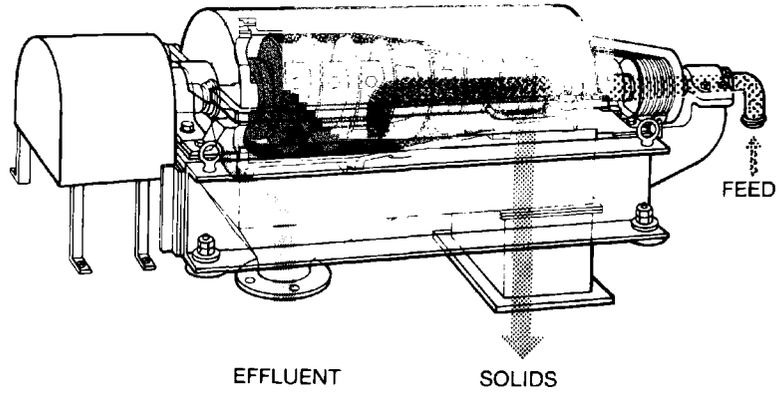


Fig. 3.11 — Decanter centrifuge with internal screw that separates bulky solids from liquids. From Alfa-Laval (1978).

clarification of tallow (2) dewatering of coagulated blood solids and (3) dewatering of solids from effluent. These applications are all concerned with clarification, i.e. removal of solids from liquid. A slurry which might contain 30–40% solids can be fed into a decanter. Separation occurs between the solid heavier phase, which goes to the outside of the rotating drum at 3000–4000 rpm, and the liquid phase, which is close to the axis of rotation of the machine. Solids are transported along to the conical section

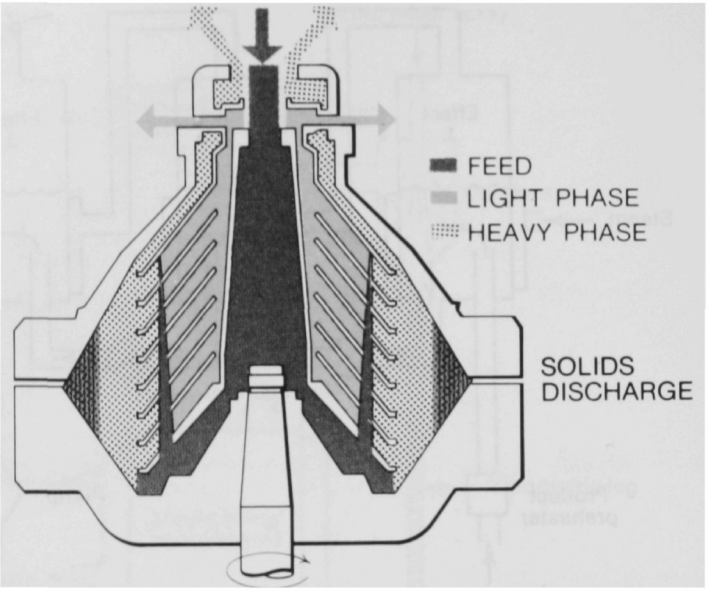


Fig. 3.12 — Disc-type high-speed centrifuge separates insoluble fines from incoming feed material through a high g-force action. From Alfa-Laval (1978).

with the aid of a screw and discharged. The screw rotates in the same direction as the drum but at a slightly slower speed which has the same effect as a counter-rotating screw. Liquids are discharged at the opposite end of the centrifuge from ports located close to the axis of rotation.

High-speed disc centrifuges are well suited to final clarification of tallow (polishing) and purification where one solid phase is separated from two individual liquid phases. Separation takes place in the disc stack of the centrifuge. Solids accumulate in the widest part of the bowl and are discharged intermittently by opening a discharge slit. There are differing methods for discharge of solids, which basically differ in the length of time the discharge port is open. Clarified and purified liquid is discharged axially at the top of the centrifuge (Fenton, 1984).

An efficient type of continuous drier for blood and other high-moisture substances is the Ring Dryer (trademark of the Dupps Corporation, Columbus, Ohio) illustrated in Fig. 3.13. The drier operates as follows:

(1) Heated air enters the furnace (A) and is drawn through the ducting (B) to the disintegrator (C).
(2) The product to be dried enters through the feed hopper (D) into the disintegrator (C) and both flow through ducting (E,F and G).
(3) As heated air passes through the disintegrator (C), it picks up the product.
(4) The air and entrained product enter the manifold (H) where the dried product is separated from the moist product by a patented process.
(5) Moist product is recirculated through the system, re-entering duct (B) and again flowing through the disintegrator (C) and the duct system.

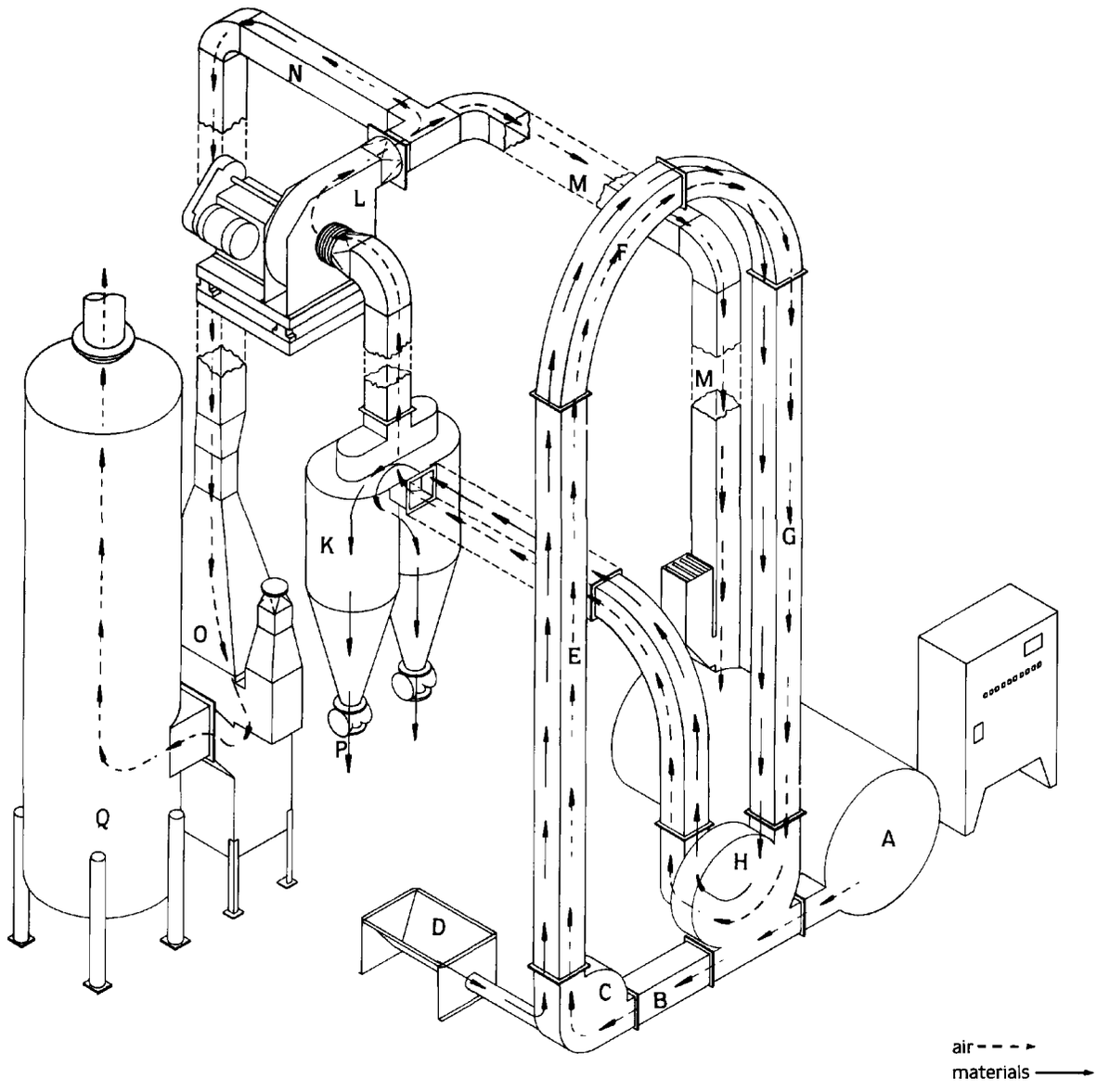


Fig. 3.13 — Ring Drier — arrows show flow of air and materials through the system. Courtesy of the Dupps Corporation, 1985.

(6) Dried product is drawn into cyclone collector (K) where it is separated from the air.
(7) Air leaves the cyclone collector (K) and exits through blower (L).
(8) Dried product leaves the cyclone collector (A) through duct (M). The remaining air from the blower flows through duct (N), venturi (O), and then through the packed tower scrubber (Q) to the atmosphere.

A major advantage of the Ring Drier is recycling of 60% of the heated air back through the drier, which helps to make drying of a high-moisture substance such as blood economically feasible.

Blood is difficult to dry in a cooker/drier because it tends to stick to the heated surfaces of the drier. It is also a characteristic of blood that, upon reaching a certain moisture content, it has a glue-like consistency that puts a tremendous strain on the

agitator in a cooker. Much of the liquid can be removed from blood by batch or continuous coagulation (facilitated by heating to 90°C (194°F)). The coagulum might then be dried in a cooker or ring drier.

Modern methods of blood processing include chemical methods and hyperfiltration (Hansen, 1983). Because of expense, these methods are often most applicable for blood or blood components that are to be used in edible products.

For more information, see Chapter 9.

COMPARISON OF RENDERING METHODS

As has been stated earlier in this chapter, generally rendering methods can be categorized into batch or continuous, dry or wet. The modern continuous wet-rendering system is referred to as low-temperature or mechanical rendering. This comparison of rendering methods from Fernando (1984) will be useful in understanding the various advantages and disadvantages of each method. However, it is not meant to infer that there is one 'best' method for all applications, for the best method or system will often depend upon the application.

High-temperature rendering systems

High-temperature rendering is rendering carried out above 100°C (212°F).

Digestor wet rendering

This method of rendering is being phased out, but a few plants still use it. Raw material is loaded into a vertical digestor, which is simply an enlarged version of the domestic pressure-cooker. Water is added if the raw material is dry, and steam is directly injected into the material through perforated plates at the bottom of the digestor.

Advantages

(1) This system can produce a good-quality tallow.

Disadvantages

(1) This system has long cook times.
(2) It is very labour-intensive.
(3) Up to 25% of meal is lost in the gravy.
(4) To produce good-grade tallow, viscera must be cut and washed.

Dry batch rendering

Advantages

(1) There is very little loss of material from the cooker.
(2) It can cook, pressurize and sterilize in the same vessel.
(3) Because this is a batch operation, separate cookers can be set aside for different materials, e.g. edible tallow, margarine tallow, inedible tallow etc.
(4) Vent steam from the cookers can be used to provide hot water.

Disadvantages

(1) Dry batch rendering produces a darker tallow compared with tallow from wet rendering or low-temperature rendering (LTR).
(2) High-temperature cooking and pressing produces fines, which pass on to tallow and are lost to effluent from the tallow-polishing centrifuges.
(3) Dry-rendered meal has a fat content of 10–16% compared with meal from LTR systems where the fat level is 3–8%.
(4) To produce good-quality tallow, raw material must be cut and washed, which results in loss of fat and protein and addition of water to the raw material. A moisture content of 63% in the raw material corresponds to 35% water added, which is excessive. Water is often added by indiscriminate hosing and gut washers, and to facilitate conveying.
(5) This process has difficulty rendering gelatinous material such as slunks (unborn calves).
(6) It is difficult to keep a plant clean and tidy. The process is not contained in enclosed vessels and therefore cooked products could be recontaminated.
(7) It is difficult to control the end-point of cooks.
(8) There is a high consumption of steam if vent steam is not recovered as hot water.
(9) Dry-rendering cookers are not efficient driers.
(10) The process is labour-intensive.

Continuous dry rendering

In this process dry rendering is carried out continuously in one cooker, which typically replaces two to five batch cookers.

Advantages

(1) Being continuous, the process requires less floor area and less labour than dry batch rendering.
(2) There is very little loss of material from the cooker.
(3) Vent steam from the cookers can be recovered to provide hot water.

Disadvantages

(1) This system cannot pressurize; it therefore cannot sterilize by pressure cooking and cannot hydrolyse hair and wool.
(2) The colour of tallow is slightly poorer than that from dry batch cookers due to high cooking temperatures.
(3) This system has all the disadvantages of batch rendering except that it is not labour-intensive. (See disadvantages (1)–(9) for batch rendering.)

Semicontinuous process incorporating both wet and dry rendering

In this process crushed raw material is charged into a conventional dry-batch cooker and cooked for a short time (45–60 minutes). The cooking cycle includes a pressure cycle to ensure sterilization. Material leaving the cooker is sterilized and rendered. The tallow, process water, sludge and wet meal are separated by decanter centrifuge

and disc centrifuges. Meal is finally dried in continuous driers and the process water is evaporated in multi-effect evaporators. The concentrate, 40% total solids, is mixed with the wet meal and dried in the drier.

Advantages
(1) This system produces tallow and meal of high quality.
(2) Fat in the meal is about 8%.
(3) Approximately 40% less steam is used compared with dry rendering.
(4) The process can be automated.

Disadvantages
(1) The system has a high capital cost.
(2) High repairs and maintenance costs.

Low-temperature rendering (LTR)
In the traditional high-temperature dry-rendering process, raw material is first heated and cooked. Once the temperature in the cooker reaches 100°C (212°F), water begins to boil and evaporate rapidly. Finally the temperature rises to 110–130°C (230–266°F) at which point the meal is deep-fried in hot fat.

Because the cooker contents are subjected to temperatures above 100°C for relatively long periods, raw material must be washed to remove paunch contents and other 'dirt'. Otherwise the colour of dirt in the raw material becomes 'fixed' in the tallow and the tallow will be downgraded. Pressing, which is used to separate cracklings from tallow, produces a meal high in residual fat. To facilitate processing, operators usually overdry the meal. Thus, meal from this process is high in fat and low in moisture.

In LTR, phase separation is carried out at low temperatures (70–100°C (158–212°F)). At these temperatures the raw material need not be washed, because the colour of paunch contents and other dirt is not fixed in the tallow. After low-temperature phase separation, the tallow and wet solids are processed separately to obtain maximum yields and high product quality. Ideally the losses in the stickwater are low and the meal is low in fat and low in moisture.

LTR systems require around 0.5 kg (0.5 lb) of steam per kg (lb) of raw material, compared with dry rendering, which requires around 1.0 kg (1.0 lb) of steam/kg (lb) of raw material. Table 3.8 compares yield data for one type of LTR (MIRANZ) and dry rendering.

The yield and production figures in Table 3.8 are based on not washing the soft raw materials for the LTR. In dry rendering, where washing is necessary, fat and fat-free solids losses have been attributed to losses due to washing only, which assumes no loss of products from the dry-rendering process itself. However, in one monitored plant, 3% of the tallow production and 2% of the meal production were lost from tallow centrifuges.

No matter what rendering system is operated, profitability can be improved by ensuring maximum yields and obtaining the best possible product quality. Regular and planned maintenance of equipment would minimize repairs and maintenance

Table 3.8 — Comparison of yields — LTR and traditional dry rendering[a]

Yields	LTR	Dry rendering
Fat (%)	99.5	95.0
Fat-free solids (%)	94.0	96.0
Fat in meal (%)	8.0	12.0
Moisture in meal (%)	8.0	3.0
Tallow, ton[b]	4346.0	3909.0
Meal, ton[b]	5371.0	5421.0

[a]Based on rendering a raw material composed of 60% water, 20% fat and 20% fat-free solids and on rendering 10 tonnes/h (11 tons/h) raw material, 12h/day, 200 operating days/annum.
[b]To convert to U.S. tons multiply ton by 1.1.
Source: Fernando (1984).

costs. Rendering added water is wasteful, and renders should try not to add any water to raw material. Substantial energy costs can be saved by heat recovery or switching to LTR systems.

REFERENCES

Alfa-Laval (1978) *Process innovations for the meat by-products industry.* Stockholm, Sweden, Alfa-Laval.

Anon. (1986) Edible tallow use down; exports dip. *Render* **15** (III) 7.

Austin, D. (1949) *Better Rendering.* Cincinnati, Proctor and Gamble.

Batty, J. C. and Folkman, S. L. (1983) *Food engineering fundamentals.* New York, John Wiley.

Brennan, J. G., Butters, J. R., Cowell, N. D. and Lilly, A. E. V. (1969) *Food Engineering Operations.* London, Elsevier.

Burnham, F. (1978) *Rendering, the Invisible Industry.* Fallbrook, California, Aero.

Burnham, F. (1985) Petfood market continues to grow. *Render* **14** (1) 12.

Church, D. C. (1984) *Livestock Feeds and Feeding,* 2nd edn, Corvalis, Oregon, D & B Booker.

Dainty, R. B. (1981) *Centenary.* Chicago, Darling-Delaware.

Edwards, B. R. (1981) Protein. In *Centenary,* pp. 192–193, Chicago, Darling-Delaware.

Encyclopedia Americana (1985) s.v. Soap, by W. J. Beach.

Fenton, C. J. (1984) Edible rendering. In *Proceedings of Meat Byproducts Quality Control Workshop, Richmond, NSW, Australia 13–17 May, 1984,* pp. 59–71, Cannon Hill, Australia, CSIRO Meat Research Laboratory.

Fernando, T. (1984) Comparison of rendering methods. In *Proceedings of Meat By-products Quality Control Workship, Richmond, NSW, Australia 13–17 May, 1984,* pp. 72–82, Cannon Hill, Australia, CSIRO Meat Research Laboratory.

Filstrup, P. (1976) *Handbook for the meat by-products industry.* Titan Separator A/s, Denmark, Alfa-Laval Slaughterhouse By-products Department.

Hansen, C. L. (1983) Methods for animal waste recovery and energy conservation. *Food Tech.* **37** (2) 77.

Jones, R. (1984) Tallow quality. In *Proceedings of Meat Byproducts Quality Control Workshop, Richmond, NSW, Australia 13–17 May 1984,* pp. 13–26, Cannon Hill, Australia, CSIRO Meat Research Laboratory.

Moffat, K. (1984) Continuous rendering. In *Proceedings of Meat Byproducts Quality Control Workshop, Richmond, NSW, Australia 13–17 May, 1984.* pp. 54–59, Cannon Hill, Australia, CSIRO Meat Research Laboratory.

Morrison, K. (1987) Personal communication. Hyrum, Utah 84319, E. A. Miller Packing Company.

Romans, J. R., Jones, K. W., Costello, W. J., Carlson, C. W. and Ziegler, P. T. (1985) *The meat we eat,* 12th edn, Danville, Illinois, Interstate.

Shamberger, R. J. (1979) Is peroxidation important in the cancer process? In *Auto oxidation in food and biological systems,* pp. 639–649, M. G. Simic and M. Ravel (eds) New York, Plenum Press.

Suter, D. (1984) Meat meal. In *Proceedings of Meat Byproducts Quality Control Workshop, Richmond, NSW, Australia 13–17 May, 1984,* pp. 1–7, Cannon Hill, Australia, CSIRO Meat Research Laboratory.

Teachman, E. H. (1981) Glue. In *Centenary,* pp. 172–175, Chicago, Darling-Delaware.

Wilder, O. H. M. (1960) Byproduct feeds. In *The science of meat and meat products,* pp. 402–412, American Meat Institute Foundation (ed.), San Francisco, W. H. Freeman.

4

Hide and skin by-products

INTRODUCTION

Throughout human history people have utilized animal skins, and nomadic people still depend upon them for shelter, clothing, weapons and as food containers. Tanning developed early in man's history, when hides were treated with juices extracted from tree bark, but a great deal of art remains in this procedure and scientists are still struggling to understand this complex process. Recent production of synthetic materials to replace leather has reduced our dependence on this unique natural material, but many quality items still demand the wearing ability, superior moisture-vapour transfer and insulating properties of high-quality leather.

The hide is a very signficiant portion, 4–11%, of the weight of the live animal (Table 4.1) and consequently is one of the most valuable by-products produced by that animal.

Hides, skins and pelts are converted into a variety of consumer goods. A few examples are shown in Table 4.2. In addition to the leather portion, other parts of the original skin (for example, hair, wool, fat and trimmings) are also salvaged and utilized in a variety of ways.

TRADE IN HIDES AND LEATHER

The quantity of animals slaughtered in the U.S. from which skins or hides are available is shown in Table 4.3. Since most of the cattle hides are salvaged, it is obvious that a very significant percentage of U.S. hides enter the export market (Table 4.4). In the case of sheep pelts, however, some are imported to be converted into leather in the U.S. Many pigskins (five pigskins roughly equivalent to one bovine skin) are not salvaged for leather use; therefore, this market has a large potential for growth.

The American shoe industry has been swamped by importation of shoes from markets in which the cost of labour is significantly less than in the U.S. Table 4.5 shows how significant this has become, with 71.5% of U.S. footwear (2.5 square feet (0.23 square metres) of leather per pair of shoes) arriving from outside of the

Table 4.1 — Hide as percentage of live weight

Type of animal	Range of hide yield (percentage of live weight)	
Cattle		
Average	5.1–8.5	(average 7.0)
Average using hide stripper	4.0–6.0	(average 2% decrease)
Hereford	8.5	
Angus	7.5	
Shorthorn	6.5	
Charolais, bull, 15 months old	8.5	
Charolais, bull, 20 months old	8.3	
Charolais, bull, 30 months old	6.7	
Good steer	6.6–7.6	
Poor steer	6.4–7.8	
Good heifer	5.1–7.9	
Branded cow	6.6–7.6	
Canner, cutter	5.7–6.8	
Bull	6.7–7.5	
Bologna bull	7.0–8.1	
Sheep		
Sheep and lamb	11.0–11.7	
Swine		
Pig, vertical drum skinner	3.0–8.0	
Boar	10–12	

Bengtsson and Holmqvist (1984), Judge *et al.* (1978), Lawrie (1981), Minnoch and Minnoch (1979), Romans and Zeigler (1974).

country. This negative U.S. balance of trade may also be seen in other leather items as well as shoes. Table 4.6 illustrates leather movement and Table 4.7 shows its origins and destinations.

CLASSIFICATION

Hides are classified according to weight, to whether or not the hide is branded and the location of the brand, sex, level of animal fatness, defects, and the skill of the person removing the hide. Some of the classifications for cattle hides may be found in Table 4.8. Hides are graded according to the following:

No. 1 — A hide that is free from holes, cuts, deep scores or gouges, visible grain defects and broken grain (over 25 mm (1 in) long) and which has substantially the correct pattern and is sufficiently cured. An exception is that the rear shanks may contain one hole below the hock which is less than 25 mm (1 in) long. If a hole or score is on the welt of a brand it will still be a No. 1 hide if otherwise satisfactory.

Table 4.2 — Examples of some uses of hides, skins or pelts

Portion of hide, skin or pelt	Example of finished product
Cattle hide by-products	
Cured and tanned hides	Sole and upper leather shoes, rawhide, bags, athletic equipment, belting, unpholstery, etc.
Corium layer	Picking bands, textile shuttle holders and passers, reconstituted collagen sausage casings, cosmetic collagen products
Tail hair	Paint brushes, upholstery padding
Body hair	Felting, plaster retardant, etc.
Inside of ear hair	Imitation camel-hair brushes
Hide trimmings	Tankage, fertilizer, glue, inedible gelatin
Hide fat	Tallow
Calf skin	Light weight leather, fabric trimmings, drum heads, gloves, etc.
Hog skin by-products	
Pig skin	Gloves, belts, razor strops, shoe uppers, innersoles, upholstery, shoe counters, sausage, pork rinds, edible gelatin, glue, etc.
Hair	Upholstery padding, felting, plaster retardant
Bristles	Brushes
Sheep pelt, by-products	
Wool	Blankets, gloves, clothing, carpets, upholstery fabric, lanolin, etc.
Slats (skin after wool or fleece is removed)	Shoe and slipper uppers and lining, hat sweat bands, fancy shoes, gloves, garmets, sporting goods, diplomas, etc.
Pelts (wool or fleece left on)	Heavy coat material, moutons, shearlings
Trimmings	Glue, tankage
Horse hide by-products	
Cured and tanned hides	Shoe sole and uppers, gloves, sporting goods, luggage, belts
Domesticated land and water buffalo hide by-products	
Cured and tanned hides	Shoe sole and uppers, fancy leather goods, luggage, handbags, buffing wheels
Deer hide by-products	
Cured and tanned hides	Shoe uppers, clothing, gloves, moccasins, mukluks
Kangaroo hide by-products	
Cured and tanned hides	Shoe uppers
Exotic and fancy leathers	
Aquatic group	Frog, seal, shark, walrus, turtle
Land group	Camel, elephant, ostrich, pangolin
Reptile group	Alligator, crocodile, lizard, snake

Clemen (1927), Ockerman (1983), Tanners' Council of America (1983).

No. 2 — A hide that is off-pattern, or contains a hole, cut, deep score, or gouge less than 152 mm (6 in), or visible grain defects or warts less than one square foot (929 square centrimetres) (located above a line through the break in the hair on the fore and hind flanks).

Table 4.3 — United States animal population, slaughter and leather production for 1986

	Cattle	Sheep	Pigs
U.S. animal population (million head)	105	10	51
U.S. animals slaughtered (million head)	37	5	77
U.S. leather production (million hides or skins)	13	5	4

U.S. Department of Agriculture (1987).

Table 4.4 — U.S. hide exports for 1986

	Whole hides
Cattlehides	26 481 328
Calfskins	2 219 682
Kipskins	533 987
Croupons	481 830
Wet blue sides, not split	1 556 626
Wet blue sides, split	667 422

U.S. Department of Commerce (1987a), United State Hide, Skin and Leather Association (1987).

Table 4.5 — Production, import and export of U.S. footwear for 1986

1986	Million pairs	Percentage
U.S. Production of footwear	233.5	
U.S. Imports of footwear[a]	940.8	
U.S. Exports of footwear	13.0	
Percentage of U.S. utilized footwear that is imported		81.0

[a]U.S. imports of footwear (non-rubber) for 1986 were from: Taiwan 46%, Korea 19%, Brazil 12%, Italy 7% and Spain 4%.
U.S. Department of Commerce (1987a).

Table 4.6 — U.S. leather imports and exports for 1986

	Imports		Exports	
	Value ($1000)	Percentage	Value ($1000)	Percentage
Leather, fancy	70 841	17.4		
Bovine: glove and garment leather not fancy	63 140	15.5		
Upholstery leather	40 751	10.0		
Bovine: other, not fancy	37 780	9.3		
Bovine: upper leather	29 096	7.2		
Goat and kid leather: not fancy	25 493	6.3		
Calf and kip, upper leather	21 306	5.2		
Reptilian leather, not fancy	19 519	4.8		
All other categories	98 559	24.3		
Bovine: rough, russet and crust, wet blue, not split			58 380	18.6
Upholstery leather			42 596	13.6
Other bovine upper leather, e.g. calf and kip			36 221	11.6
Glove and garment leather			32 831	10.5
Bovine: rough, russet and crust, wet blue, split, e.g. grains			31 395	10.0
Other bovine leather			20 358	6.5
Other leather			19 968	6.4
Sheep and lamb garment leather			15 470	4.9
All other categories			56 189	17.9
Totals	406 485	100.0	313 408	100.0

Leather Industries of America (1987).

No. 3 — A hide that contains hairslips, five or more holes, cuts, deep scores or gouges, any holes or cuts 152 mm (6 in) or longer, insufficient cure, a pepper-box, warts or any defect covering 0.093 m^2 (1 ft^2) or more of the hide.

Table 4.7 — U.S. foreign trade in leather for 1986

	Percentage imports (of $406 485 000)	Percentage exports (of $313 408 000)
Argentina	32.2	
U.K.	10.6	
Italy	9.6	
Canada	6.6	
India	5.5	
West Germany	4.4	
France	3.6	
Brazil	2.7	
Others	24.8	
Korea, Republic		17.1
Canada		14.6
Italy		10.3
China, People's Republic		9.9
Hong Kong		6.3
Taiwan		5.3
Japan		5.1
Philippines, Republic		4.0
Dominican Republic		3.6
Others		23.8
Total	100.0	100.0

Leather Industries of America (1987).

Sheep pelts are graded according to wool length. These classifications are located in Table 4.9. 'Skin' is the term used for small hides, and in cattle these are those weighing less than 13.62 kg (30 lb) after curing. A 'Colorado' or 'Texas hide' indicates that the hide is branded on the butt or on the side and a 'native' refers to an unbranded hide. 'Big-packer hides' refers to hides that were removed from the carcass by skilled labour and 'country' or 'small-packer hides' indicates that the hides were removed by less-skilled labour. A 'renderer' or 'murrain hide' means that the hide was removed from an animal that died from some cause other than slaughter.

HIDE COMPOSITION

The thickness of the skin varies with species, age, sex and region of the body (thicker on the back and on the external surfaces of the limbs; thinner on the ventral and on the flexor surfaces). The skin is composed (Table 4.10) of three major layers: the surface pigmented epidermis, the underlying connective tissue corium and the deep

Table 4.8 — Packer hide selection

Selection	Description	Range of net weight in pounds	
		Conventional	Trimmed and fleshed
Slunk	Unborn calf		
Light calfskin		Less than 9	
Heavy calfskin		9–15	
Kipskin		15–25	
Overweight kipskin		25–30	
Heavy native steer	Steer hide free of brands	58 up	47 up
Light native steer	Steer hide free of brands	48–58	39–47
X-light native steer	Steer hide free of brands	30–48	23–39
Heavy butt-branded steer	Steer hide branded one or more times behind the break in flank	58 up	47 up
Butt-branded steer	Steer hide branded one or more times behind the break in flank	30 up	23 up
Heavy Colorado or side-branded steer	Steer hide branded one or more times forward of break in flank	58 up	47 up
Colorado or side-branded steer	Steer hide branded one or more times forward of break in flank	30 up	23 up
Light-branded steer	Steer hide branded one or more times	30–58	23–47
Heavy Texas steer or branded steer	Steer hide branded one or more times	58 up	47 up
Texas steer or branded steer	Steer hide branded one or more times	30 up	23 up
Heavy native cow and heifer (plump)	Hide from female bovine free of brands	53 up	43 up
Ligh native cow and heifer (plump)	Hide from female bovine free of brands	30–53	23–43
Heavy native cow and heifer (thin or spready)	Hide from female bovine free of brands	53 up	43 up
Light native cow and heifer (thin or spready)	Hide from female bovine free of brands	30–53	23–43
Branded cow and heifer	Hide from female bovine branded one or more times	53 up	43 up
Light branded cow and heifer (plump)	Hide from female bovine branded one or more times	30–53	23–43
Heavy native bull	Hide from bull free of brands	58 up	
Heavy branded bull	Hide from bull branded one or more times	58 up	

[a]Multiply by 0.454 to convert to kg.
Leather Industries of America and U.S. Hide, Skin and Leather Association (1985), Price and Schweigert (1971), Tanners Council of America (1972).

subcutis. The thin epidermis covers the surface and extends downward as tubular invaginations and forms part of the surface of the hair follicles. The underlying corium is associated with the hair follicles. The upper portion of the corium contains sebaceous glands, the erectile follicular smooth muscles and elastic, reticulum and collagenous fibres. The deeper portion of the corium is interwoven bundles of collagen. In bovine animals the hair root extends about one-third the depth of the corium, but in swine the hair follicle penetrates the corium and extends down into the subcutis (see Fig. 4.1). The subcutis consists of a loose membrane network of

Table 4.9 — Grades of shearlings or sheep pelts

Grade	Wool length[a]
Number 4	Bare to $\frac{1}{8}$ in
Number 3	$\frac{1}{8}$–$\frac{1}{4}$ in
Number 2	$\frac{1}{4}$–$\frac{1}{2}$ in
Number 1	$\frac{1}{2}$–1 in
Fall clip	1–2 in
Wool pelts	$1\frac{1}{2}$ in

[a]Multiply by 2.54 to convert to cm.
National Hide Association (1979), Price and Schweigert (1971).

Table 4.10 — Skin layers and two methods of splitting hides

Side	Skin	Leather	
		Five layers	Four layers
Hair-side	Epidermis, pigmented, thin	Buffing	
	Grain layer, papillary	Machine buff	Thop grain
	Corium, dermis, derma, cutis vera, connective tissue, greatest part of hide	Deep buff Split	Split
Flesh-side	Subcutis, attachment, filled with fat	Slab	Slab

Moulton and Lewis (1940), Price and Schweigert, (1971), Tanners' Council of America (1983).

collagen and elastin fibers. The subcutis portion contains fatty deposits (especially in swine) and determines the tautness or slackness of the skin.

The chemical composition of the skin (Table 4.11) varies with the age of the animal, its sex, the fat level of the animal and the treatment the hide has received after being removed from the carcass. In general, the hide is low in fat and minerals and is high in protein (collagen). This protein increases dramatically and is a major component when the hide is converted into leather. Hair is composed almost entirely of the protein keratin, which normally accounts for 6–10% of the total hide protein.

HIDE CURING

The quality of leather to a large degree depends on the techniques used for hide removal (flaying) (see Fig. 4.2) and the processing that takes place in the slaughter

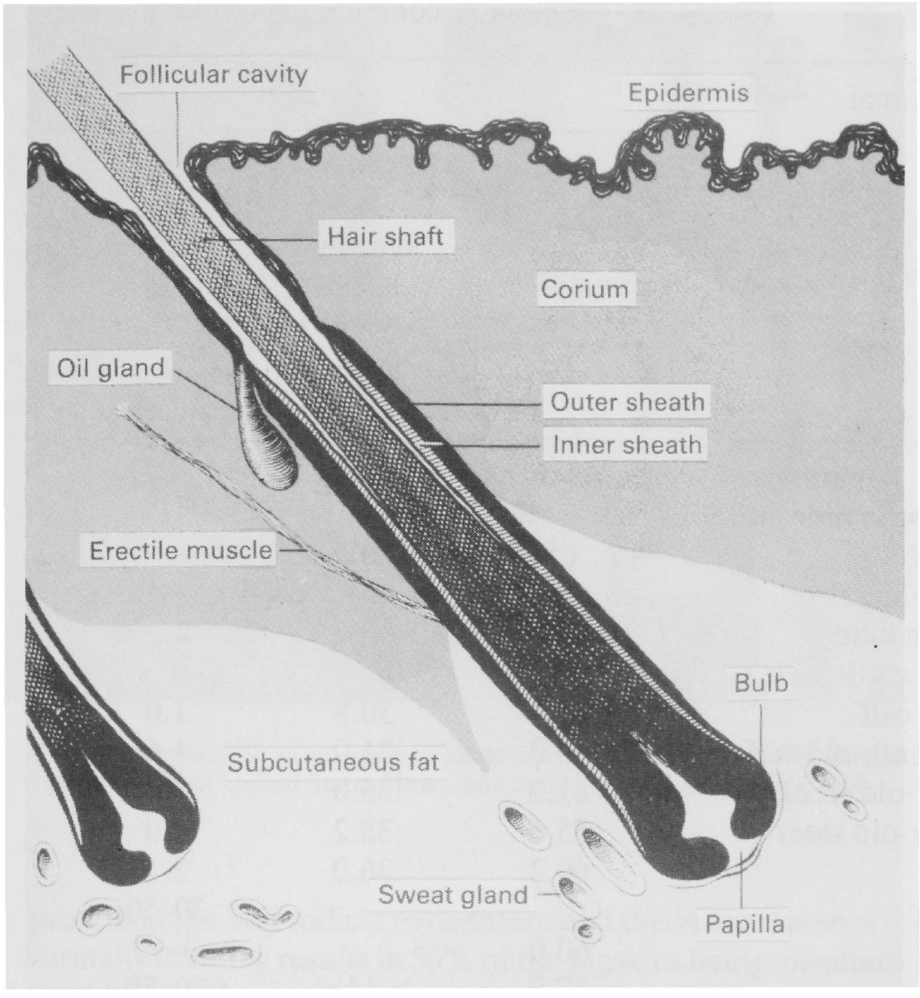


Fig. 4.1 — Vertical section of normal hogskin. Price and Schweigert (1971).

facility. The operations performed here are: hide removal, preservation, fleshing, trimming, selection and grading, storage and shipping, although fleshing and trimming sometimes precede preservation. All of these steps need to be done properly to produce a quality final leather product.

Hide removal from cattle, sheep and goats is accomplished today in the U.S. by two different basic techniques: the time-honoured knife-skinning technique, using either the conventional skinning knives or the newer air-driven reciprocating skinning knives, or the more modern technique for hide removal — the hide-pulling technique. Another technique used in some countries is to pump compressed air into the carcass to cause hide separation. The knife removal technique requires highly skilled personnel since it is very easy to accidentally cut or score a hide, which drastically lowers its value. It takes three to five knifemen approximately 120 seconds to remove a cattle hide manually (National Hide Association, 1979). Today, in most modern plants, the hides are pulled, because hides can be removed using this technique with less-skilled labour and less hide damage, lower manpower requirements per animal dressed, less likelihood of carcass contamination and an increase in carcass yield for cattle of approximately 2% when compared to the knife-skinning

Table 4.11 — Chemical composition of hides

Age of animal	Percentage of			
	Moisture	Protein (collagen, keratin, elastin, reticulin)	Fat	Ash (phosphorus, potassium, sodium arsenic, magnesium, calcium)
Average slaughter cattle	62–70			1.0
Mature cattle hide, without hair	65	30.0		
Very fat animal			10–12	
Wet cattle hide	83.0	15.7	0.2	0.1
Air-dried cattle hide	9.1	89.9	0.2	0.8
Newborn calf	67.9	30.8	1.0	1.0
Three-month-old calf	66.0	31.0	1.6	1.4
Two-year-old steer	61.2	35.0	3.2	1.1
Four-year-old steer	55.6	38.2	6.0	1.1
Old cow	60.2	36.0	3.1	1.1
Sheepskin			30–50	
Goatskin	60.0		3–10	
Pigskin	37.0	14	30–50	
Cured cattle hide	44–48	41		14–16 (including tanning metals)

Aten *et al.* (1955), Biedermann *et al.* (1962), Henrickson *et al.* (1984), Moulton and Lewis (1940).

technique. This 4.54 kg (10 lb) of reduced weight of the hide is because the stripper pulls the hide from the fell rather than from the carcass itself and this reduces shrinkage of the hide in curing. To accomplish hide-pulling, the hide is skinned from around the legs, butt and head, usually with air-operated reciprocating knives (see Fig. 4.2) and then clamps are attached to the hide. Usually the hide is first pulled sideways from the chest area. Another set of clamps is attached and the hide is then pulled down (may be pulled up with some equipment, but this normally increases carcass contamination) off the carcass. Careful control by the skinner is required to prevent cracking of the epidermal layer in areas where the stress is the greatest. Hides can be pulled from cattle at the rate of 80 (two knifemen)–225 per hour with one piece of equipment and two knifemen.

Hogs (pigs) are normally scalded in 57–71°C (135–160°F) hot water until the hair slips (most frequently used, 4.5 minutes in 59–63°C (139–145°F) water). This heating

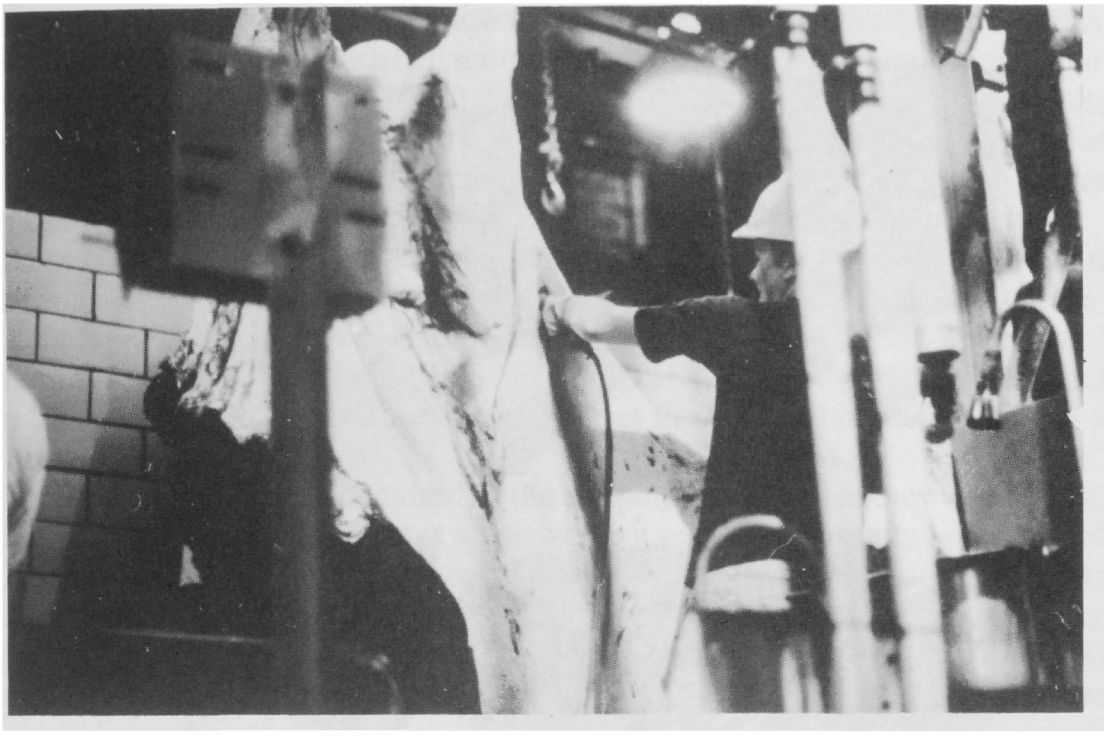


Fig. 4.2 — Hide removal with an air-operated reciprocating knife to prepare the carcass for hide pulling. From United States Hide, Skin and Leather Association (1983).

causes the protein in the hair follicle to denature and this is turn loosens the hair (see Fig. 4.3). Normally scalding results in 50% of the pigskins being unsuitable for upper shoe leather. Along with scraping, it produces pigskins that are 10% thinner and which have 10–23% less tensile strength. Overscalding causes the hair to 'set' making it difficult to remove. This is caused by contraction of the skin around the base of the hair, which makes it difficult to separate from the skin. Severe overscalding will cook the skin, making it useless for leather, and will often cause the carcass to be condemned — unusable as human food. The 'hard-hair season' (September to November in the U.S.) is the time of year when hog hair is much more difficult to remove because of the cyclic change in the hog's coat due to the arrival of cold weather. A number of chemicals are approved for use in the scalding water to aid in hair and scurf removal and a few of these allowed by USDA for this purpose (Ockerman, 1983) are: caustic soda (sodium hydroxide, NaOH), lime (in water it becames calcium hydroxide, $Ca(OH)_2$) sodium carbonate (soda ash, washing soda), sodium hexametaphosphate ($(NaPO_3)_6$), sodium dodecylbenzene sulphonate ($C_{12}H_{25}C_6H_4SO_3Na$), sodium *n*-alkyl-benzene sulphonate ($NaC_6H_5SO_3$; alkyl group replaces sodium and is predominantly C_{12} and C_{13}), trisodium phosphate (Na_3PO_4), dioctyl sodium sulphosuccinate ($C_{20}H_{37}Na_7S$), sodium sulphate (Na_2SO_4), sodium lauryl sulphate ($C_{12}N_{25}NaO_4S$), sodium tripolyphosphate ($Na_5P_3O_{10}$), methyl polysilicone ($(((CH_3)_2SiO)_x$), sodium metasilicate (Na_2SiO_3) and sucrose ($C_{12}H_{22}O_{11}$). After scalding, the hog carcass is placed in a dehairing machine ('polisher') for 15–30 seconds; this machine consists of rotating shafts to which metal tip scrapers are attached. The carcass is positioned on U-shaped bars and the action of the scrapers rotates the carcass and their scraping action, along with

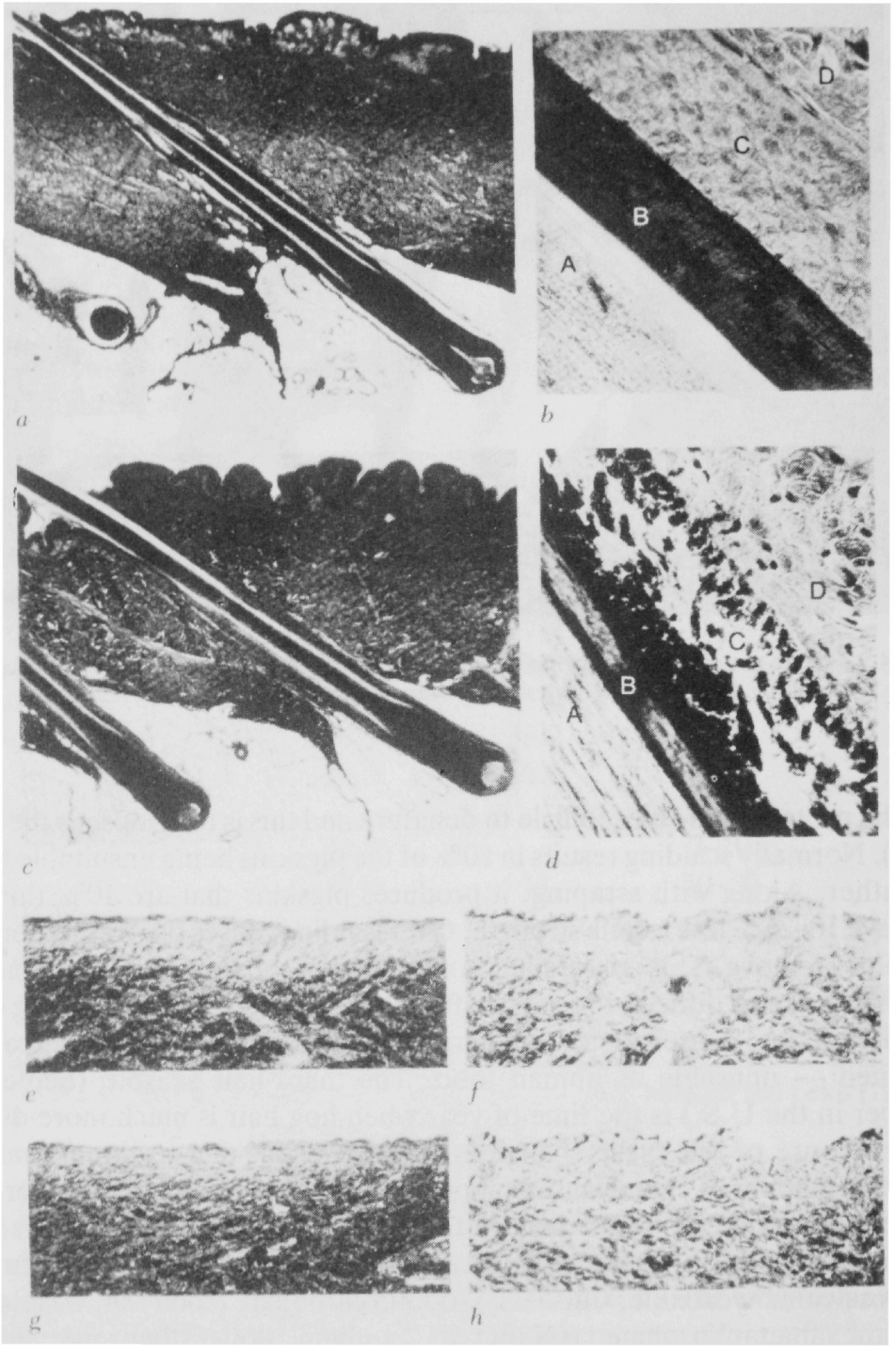


Fig. 4.3 — Changes in hog skin during hair removal. (a) Vertical section of normal hogskin, ×21. See Fig. 4.1 for identification of structures. (b) Magnified longitudinal portion of normal hair shaft (A) and adjacent tissue; inner hair sheath (B); outer hair sheath (C); and corium (D), ×330. (c) Vertical section of properly scalded hogskin. Compare with (a) for separation of tissues around hair and changes in appearance of epidermis, ×24. (d) Magnified longitudinal portion of scalded hogskin. Note separation of outer hair sheath (C) as compared with that shown in (b), ×330. (e) Hogskin dehaired and normally singed, ×20. Compare with (f). (f) Hogskin dehaired and excessively singed. Note markedly damaged grain layer, ×20. (g) Grain damage produced by normal shaving, ×22. Compare with (h). (h) Grain damage produced by excessive shaving, ×22. From Price and Schweigert (1971).

a hot-water (60°C, 140°F) spray removes the hair. Hair, in places where it is difficult to remove is hand-scraped with bell scrapers and/or shaved, and the remaining hair is often singed with a gas flame-torch, taking care not to hold the flame in one area too long, so as to avoid burning the skin. In some areas of Europe the hog is placed for a few seconds into a high-temperature furnace, which removes the remaining hair and sterilizes the surface, but this treatment also denatures the protein in the skin.

At one time in the U.S., hog carcasses were depilated after passing through the dehairing machine by dipping the carcass in a hot 121–149°C (250–300°F) mixture of rosin and cottonseed oil for 6–8 seconds. This coating was allowed to plasticize by cooling. When this material was peeled from the carcass it took with it the remaining hair. This treatment temperature also denatures the skin and renders it useless for leather production.

Pigskins that have been dehaired, if the temperature to which they were exposed during scalding or other slaughter steps was not excessive (usually less than 58°C (137°F)), can be removed from the carcass or a portion of the carcass (e.g. belly) and used for production of leather (e.g. Hush Puppy leather). In some countries, a skin that is to be pulled and utilized for leather is protected by a covering during scalding to keep it suitable for grain-leather manufacturing. The Wolverine skinner separates the skin from the carcass or a portion of the carcass by using grips that attach to the skin (e.g. the loin with the belly attached) with a clamp on a rotating drum-like device. The skinner pulls this portion of the carcass through a knife that separates the pigskin from the fat and lean tissue. The pigskins then go through a fleshing machine between a rubber roller and a roller with cupped knives, which removes all but about 3% of the fat from the skin. The pigskins are then refrigerated and shipped to the tanner.

A Townsend skinner has a burred drum that pulls the pigskin under a stationary knife and separates the skin and some fat from the other tissue. This skinner is often used to remove the skin from the dehaired ham or loin or belly and the skin and some adhering fat is used for pork rind or crackling or gelatin production. The gelatin industry uses approximately 50% of currently available U.S. pork skins. Some undenatured pork skins are used in the human burn/grafting medical area after the hair has been removed by a laser. In some countries there is a large consumption of pigskin as food, and in others pigskin is used as a filler in sausages and pies.

Hogs can be skinned with a knife rather than scalding and dehairing, but considerable skill is required due to the softness of the fat. A pulling technique similar to the one used for cattle is often used for hogs, except the pigskins are usually pulled up; however, there is interest in a down-puller to improve sanitation. Other mechanical skinners have a 'peeling' type action which removes the skin transversely, sometimes with a pulling action and sometimes with a mechanism that pushes the skin and carcass apart. The mechanical pulling of hides is gaining popularity due to energy and labour savings when compared to scalding. This technique produces 0.6–0.7 m^2 skin (6–7 ft^2) that is very useful for leather production since it has received no heat treatment. This technique has not received wider usage because it results in a 6–8% loss in carcass weight due to skin removal, and because it is slower (150–300 per hour) than scalding, which can handle 750–850 per hour.

Goatskins are more valuable than sheep skins because they are larger and produce a better-lasting leather.

Sheepskins require a longer time (up to several hours) to cool after slaughter than do other hides because of the large quantity of wool and grease in the wool they contain. They should be spread out or hung to cool (to lose body heat) before salting. When placing the salted skins in a pack, they are not piled more than ten skins deep and are transferred to new stacks every day or two.

Hides in the rendering area are sometimes removed by punching a hole in the skin and using compressed air (1.05 kg/mc^2 or 15 psi) to blow the skin off the carcass.

After hide removal from any animal, the hide should be quickly cured to arrest bacterial and enzymatic decomposition or spoilage. This is particularly true with pigskins, in which traditional salt-curing does not work as well. Pigskins deteriorate faster than cattle hides. For them, solvent dehydration may be used or the uncured hide may go directly to the tanning operation (usually chrome). Drying may be used to preserve the hide or, more commonly, salt may be used as the curing ingredient. There are four basic techniques used. These methods are air-drying, salt-pack curing, mixer curing and raceway curing.

In areas with low relative humidity, skins and hides may be air-dried. The methods of air-drying are often classified (Aten *et al.*, 1955) as follows:

1. Drying on the ground, with the hide pegged down or weighted with stones to prevent wrinkling. Due to air flowing only on one side of the hide, this method produces a high percentage of deteriorated hides and is usually not recommended.
2. Drying by suspension on an angled frame properly orientated to the sun (frame-drying).
3. Drying by suspension of the hide, with the flesh-side up over thin cords or wires. The inside hair should be prevented from touching the inside hair on the other side of the folded skin to encourage maximum air flow (line-drying). Drying over a pole causes putrefaction where the pole contacts the hide and retards drying.
4. Tent or parasol(umbrella)-drying. Hides are supported over the ground in the shape of a tent or a parasol by wires, posts and cords connected to pegs in the ground.

The oldest salt-curing method, and one that is still used on a small percentage of hides today, is the salt-pack curing method (see Table 4.12 and Fig. 4.4) in a 10–13°C (50–55°F) hide cellar. The ideal relative humidity is 85–90% and there should be good ventilation but no draughts. Salt-pack curing is simply a flesh-side up stack of hides (usually three to four feet high) with approximately 454 g (1 lb) of salt (grain size of 2–3 mm (0.08–0.12 in) is the most desirable) per 454 g (1 lb) of hide, spread evenly over the flesh-side of each hide in the stack. The hides are stacked so that the edges of the stack where the hide must be folded (minimum salt depth of 2.54 cm (1 in) in this area and extra salt placed on the upward hair-side), are higher than the centre. This is done to retain the maximum amount of brine, to reduce hide shrinkage, and to create a better cure. This salt level controls bacterial growth and draws moisture out of the hides, which drains onto the floor. Preservatives are often used with salt-pack curing and 1% sodium fluoride (NaF, this is a poison and the dust should not be inhaled) or 1% naphthalene ($C_{10}H_8$) plus 1% boric acid (H_3BO_3)

Table 4.12 — Pack-salting, requiring a minimum time of 30 days and yielding 75–85% of green hide weight

Weight (lb) hides	Operation or activity	Composition[a] or change
Green		
100	Receive hides from slaughter	62–70% water, 30–35% hides
100	Trim ears, snout and tail	3% loss; 3 lb trim to rendering
97	Salt hides into pack 1.22–1.52 m (4–4.5 ft tall), little pitch for short hair, 15.2 cm (6 in) spread for long hair	0.5–3 lb of rock salt (40% No. 1 rock salt, 60% No. 2 rock salt) per 1 lb of hide
97	Cure in pack for 30 days; 50–60°F or 10–16°C	15–17% net loss in weight; 25–35 lb loss in water, 6–13 lb uptake of salt, 13–17 lb loss of salt to sewer[b]
Cured		
82.5	Take hides from pack, inspect and bundle	Reclaim 60% original salt used and mix with new salt or discard and use all new salt
82.5	Move hides to storage or load for shipment	—
82.5	Deduct tare allowance, 3% salt, 1.5% manure	—
79	Net shipping weight to tannery	12–16% salt, 35–45% water, 40–50% hide substance

[a]Multiply pounds by 0.454 to convert to kilograms.
[b]Most modern processors in 1987 recycle excess brine and do not discharge it. Also the use of evaporation ponds decreases discharge to sewers.
Biedermann *et al.* (1962), Minnoch and Minnoch (1979), Romans and Ziegler (1974).

based on the weight of salt has been used successfully. Other salt additives might include zinc oxide (ZnO) or sodium metabisulphite ($Na_2SO_2O_5$) in various combinations. A hide pack will hold approximately 24.2 kg (53.4 pounds) of green hides and salt per 0.029 m^3 (1 ft^3). The hides in the stack are usually allowed to cure for 20–30 days (cattle) but would keep for one to two years; however, if the hide remains in the pack too long, salt stains will result. Salt is usually not re-used, since it may become contaminated with salt-resistant bacteria, but if it is re-used it should be sterilized by heating (also removes protein by flocculation) or mixing with a disinfectant and dried. The use of 2% sodium silicofluoride (Na_2SiF_6) has been found useful for this purpose (Aten *et al.*, 1955).

The mixer curing method (hide processor) is used today, particularly in smaller

Fig. 4.4 — Salt-pack method of curing hides. From United States Hide, Skin and Leather Association (1983).

plants where floor space is limited (see Fig. 4.5). The mixer looks and operates much like the familiar cement mixer and may be loaded by conveyors, dump hoppers, lift trucks or by hand. Often an initial chilling and washing cycle 13°–16°C (55°–60°F) with clean water for 10–30 minutes is used. A mixer can handle between 250 and 400 cattle hides (1000–2000 pigskins) at one time and is filled with a saturated salt brine solution, or fresh salt may be added in the proportion of 20–24% of the weight of the hides. Often a chlorinated lime or similar bacterial or mould deterrent is also added. The hides are rotated in the mixer for six to twelve hours (3–3½ rpm). This rotation is continuous in the initial part of the cycle, but is reduced to five minutes per hour in the later part of this curing procedure. When the hides are removed from the mixer they are wet and excess water must be removed from them. This is accomplished by passing a folded hide (flesh–side out) through a wringing machine to squeeze out the excess liquid, or by hanging the hides and allowing them to drip-drain.

Raceway curing is the most common method of curing hides today (see Table 4.13 and 4.14). A very large percentage of all American hides are cured by this technique. The raceway-shaped tank ('raceway vat') is agitated by two overhead paddle wheels (each three feet in diameter with six blades which dip 25–41 cm (10–16 in) into the brine and rotate at 12–16 rpm) which circulate the brine and keep the hides moving (see Fig. 4.6). A typical 50 000-gallon (189 250 l) raceway tank could hold from 800 to 1200 (fleshed) cattle hides and is filled with a saturated salt brine. Another popular size raceway is a 15 000-gallon (56 775 l) tank that will handle 550 cattle hides at one time. The brine solution is sampled frequently and maintained at 98% salinity by addition of salt as necessary, or by running the brine through a rotary screen to remove hair and fat and then to a lixiviator which also filters the brine and

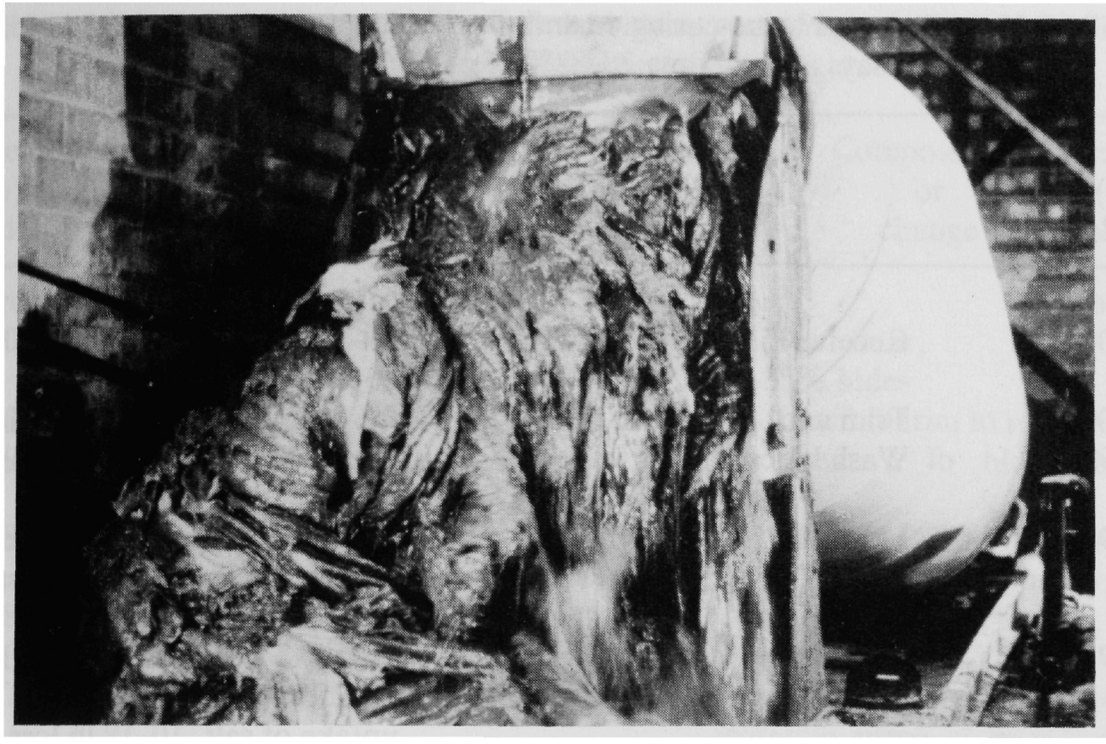


Fig. 4.5 — Mixer curing of hides. From United States Hide, Skin and Leather Association (1983).

keeps the brine near the saturation point. It requires approximately 1.8 kg (4 lb) of saturated brine for each 454 g (1 lb) of green hide. Bactericides are added to the brine to control the growth of proteolytic bacteria, which, if allowed to grow, can damage the grain surface of a hide. The materials in Table 4.15 have been found useful for this purpose (Aten *et al.*, 1955).

Others find that 0.3% (of hide weight) sodium fluoride (NaF) is successful. There are also several ready-mixed patented formulations sold under several brand names as curing agents.

Hides are normally cured in the raceway for approximately 16 hours. When the hides are removed from the curing raceway they are wet and, as in the mixer-curing technique, are passed through a wringing machine to squeeze out liquid, or are hung on hooks and allowed to drip-drain.

Pit-curing or vat-curing is a modification of raceway curing and the salt-packing techniques in which the hides are salted down (151–227 g ($\frac{1}{3}$–$\frac{1}{2}$ lb) of No. 1 rock salt per 454 g (1 lb) of hide) in a 1.2–1.5 m (4–5 ft) pit and the pit flooded with a saturated brine (see Table 4.16). In this technique the brine is not agitated and the curing time is 24–33 hours. This technique is not as popular as the raceway curing method because it is slower and does not produce as uniform a cure.

Since pigskins are not preserved as effectively by salt as cattlehides, other techniques have been evaluated. One procedure that has proven satisfactory is a 20% float containing 1% sodium bisulphite ($NaHSO_3$) and 1% acetic acid (CH_3COOH) based on the weight of the skins. This procedure has been effective in holding pigskins for 13 days at ambient temperature.

There are also non-salt methods of cattle-hide curing that have been suggested. These include the sodium sulphite/acetic acid procedure previously described for

Table 4.13 — Agitated brine-curing of unfleshed hides, requiring a minimum of 3 days and yielding 78–82% of green hide weight

Weight (lb) hides	Operation or activity	Composition[a] or change
Green		
100	Receive hides from slaughter	65–70% water, 30–35% hides
100	Trim ears, snout and tail	3% loss; 3 lb trim to rendering
97	Wash hides	2% loss; 2 lb blood and manure
95	Move hides to raceway	4 lb of brine per 1 lb of hide, maintain brine at 94–97° salometer
95	Cure in moving brine for 24 hours	15–17% net loss in weight; 20–25 lb loss in water, 8–12 lb uptake of salt, 10–18 lb loss of salt to sewer[b]
Cured		
Wet	Remove from brine and drain on horses, 48 hours	Loss of excess brine
79	Remove from horses, inspect, add 1 lb fine salt, bundle	1 lb uptake of salt
79	Move hides to storage or load for shipment	10–15% salt, 40–45% water, 35–45% hide substance

[a]Multiply pounds by 0.454 to convert to kilograms.
[b]Most modern processors in 1987 recycle excess brine and do not discharge it. Also the use of evaporative ponds decreases discharge to sewers.
Biedermann *et al.* (1962), Minnoch and Minnoch (1979).

pigskins, which can also be utilized on cattle hides. Also suggested has been solvent processing (acetone at pH 4.5–5.0, ether–alcohol, or ether–alcohol and ether-ester), which requires more sophisticated procedures, but the hides would be stable as long as they did not come in contact with water. Another suggested technique is the biocide-curing system which has been utilized in South Africa due to severe restrictions on salt. Gamma radiation as a method of curing hides has been successfully attempted, but currently this is not being used commercially.

Fleshing is another major step necessary in producing a quality hide. The fleshing machine removes approximately 9.1–11.3 kg (20–25 lb) of material per hide (averages 8.2 kg (18 lb) of fat and flesh per 45.4 kg (100 lb) of hide and the rest is hair and manure). Usually the trade agrees upon a 16% loss due to fleshing. The fleshing machine can flesh 90–125 hides per hour. Originally, this was a very time-consuming and labour-intensive task accomplished with a hand-held knife, but today fleshing

Table 4.14 — Agitated brine-curing of fleshed hides, requiring a minimum of 2 days and yielding 62–68% of green hide weight

Weight (lb) hides	Operation or activity	Composition[a] or change
Green		
100	Receive hides from slaughter	65–70% water, 30–35% hides
100	Trim ears, snout and tail	3% loss; 3 lb trim to rendering
97	Wash hides	2% loss; 2 lb blood and manure
95	Flesh and demanure with machine	12–18% loss, 12–15 lb fleshing to rendering, 1–3 lb manure
80	Trim pattern	3–4% loss, 3 lb trimming to rendering
77	Move hides to raceway	4 lb of brine per lb of hide, maintain brine at 94–97° salometer
77	Cure in moving brine for 24 hours	15–17% net loss in weight, 20–25 lb loss in water, 7–10 lb uptake of salt, 10–15 lb loss of salt to sewer[b]
Cured		
Wet	Remove from brine and pass through wringer	Loss of excess brine
65	Inspect, add 1 lb fine salt, bundle	1 lb uptake of salt
65	Move hides to storage or load for shipment	12–15% salt, 40–50% water, 35–45% hide substance

[a]Multiply pounds by 0.454 to convert to kilograms.
[b]Most modern processors in 1987 recycle excess brine and do not discharge it. Also the use of evaporation ponds decreases discharge to sewers.
Biedermann *et al.* (1962), Minnoch and Minnoch (1979).

machines are utilized (see Fig. 4.7). The fleshing machine has two spinning cylinders; the top one contains a sharp helical blade (see Fig. 4.8) which shaves flesh and fat from the hide as it is passed between the cylinders. The hide is required to make two passes through this machine with one-half of the hide being fleshed at a time. At the same time as the upper cylinder is fleshing the hide, the lower cylinder, which contains dull blades, removes manure and other foreign material from the hair side of the hide. The distance between the two cylinders must be adjusted (usually automatically) to prevent damage to the hide, and to accommodate varying lengths of hair and varying quantities of manure. The fleshing operation may be done prior to curing (usually preferable unless there is a time delay) or after the curing operation

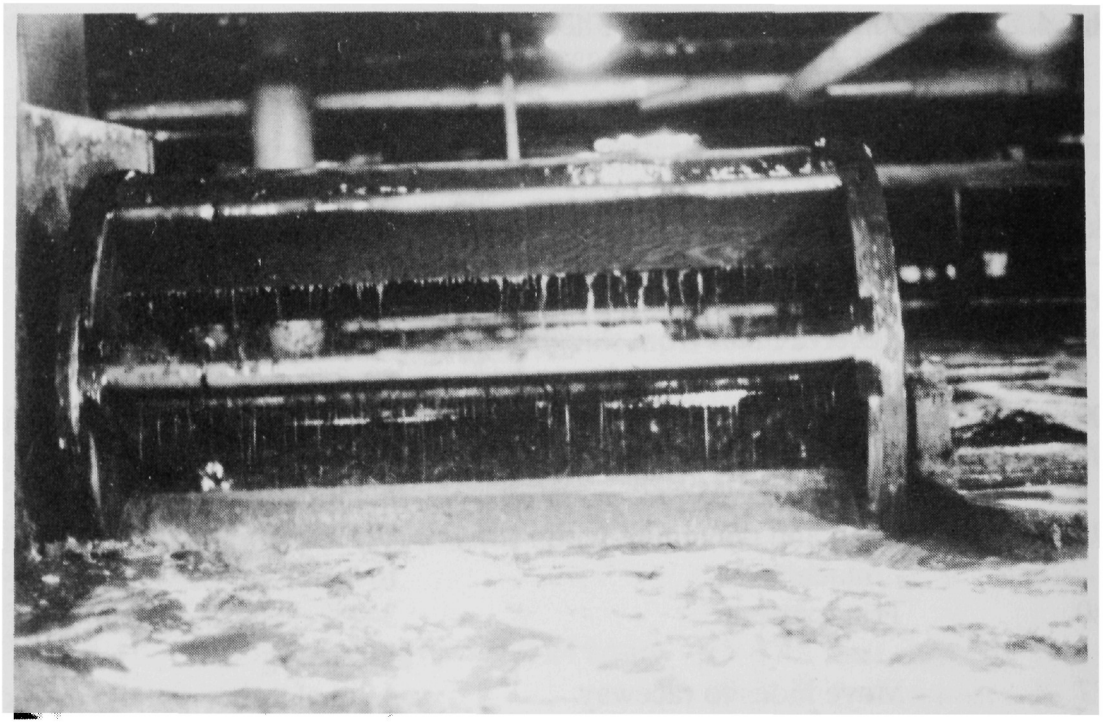


Fig. 4.6 — Raceway curing using a paddle wheel to circulate the brine and hides. From United States Hide, Skin and Leather Association (1983).

Table 4.15 — Some bactericides used in tanning

Bactericide	Parts per 100 parts of salt
Sodium fluoride (NaF)	2
Sodium silicofluoride (Na_2SiF_6)	2
Zinc chloride ($ZnCl_2$)	0.5
Mixture of	
Soda ash (Na_2CO_3)	2
Naphthalene ($C_{10}H_8$)	1

(which produces more contamination of the brine and of the flesh side of the hide, thus producing a darker hide). However, the order seems to make no difference in the final leather product. If done before curing, when the hide is warm and very flexible, the flesh and fat may be firmed and bacterial action retarded by running the hide through cold water. A firmer hide is much easier to flesh.

Fleshing residue and hide trimmings are also utilized by the by-products industry. High-pressure dry-rendering of this product is usually not feasible because fleshings tend to glue up in the cooker and their high water content is expensive to remove by evaporation. Wet-rendering systems are satisfactory and the Lycoil System (Natio-

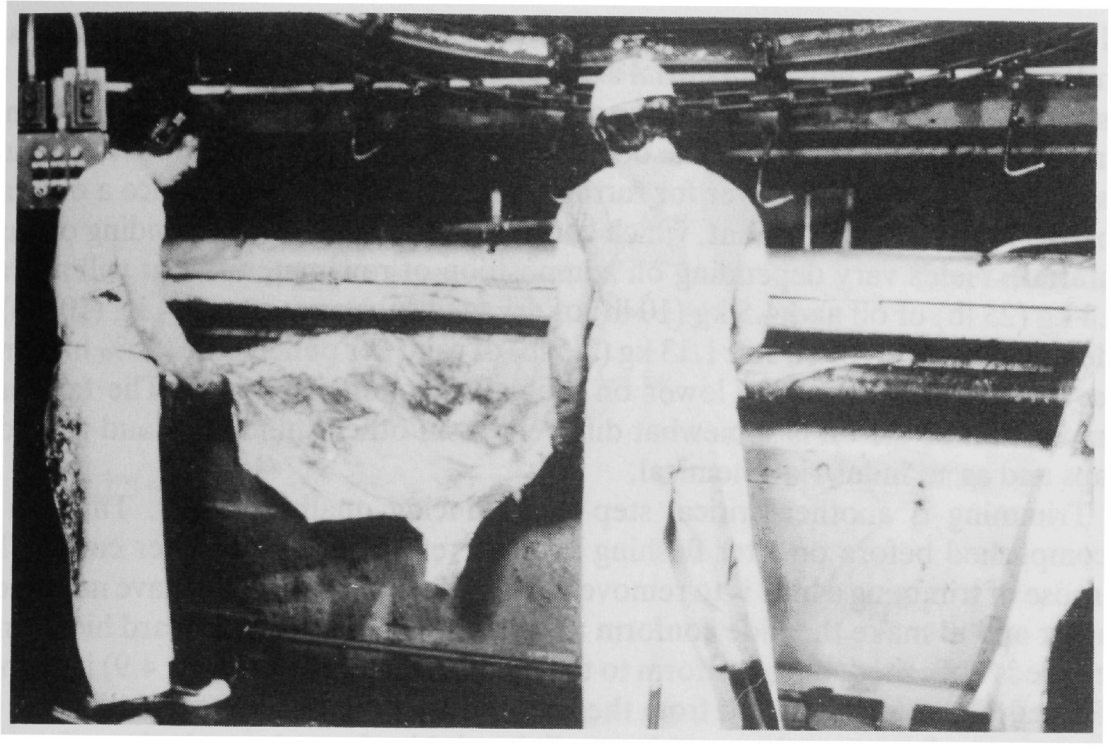


Fig. 4.7 — Fleshing of hide using a cylinder blade to remove flesh and fat from the hide. From United States Hide, Skin and Leather Association (1983).

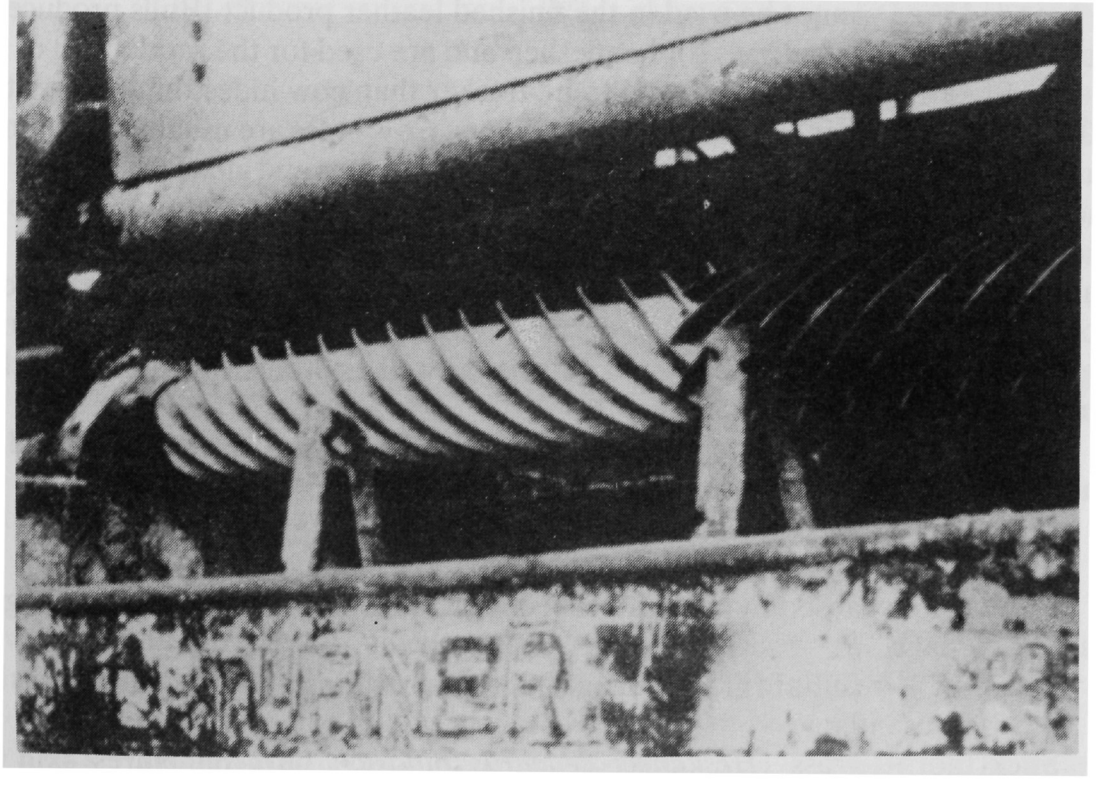


Fig. 4.8 — Helical blade used on fleshing machine to remove unwanted material. From New England Tanners Club (1983).

nal Hide Association, 1979), which is often used, is an automated centrifugal wet-rendering system. The raw material is ground, water and fat are removed from the tissue centrifugally, and the fat is then separated from the water centrifugally (can be done by simple heat settling). The defatted and partially dewatered (50% moisture) tissue is then placed in a dryer for further moisture removal to produce a dry–cake tankage-type feed supplement, which contains 40–60% protein depending on input material. Yields vary depending on composition of raw material, but will average 11.3 kg (25 lb) of oil and 4.5 kg (10 lb) of dry feed substance per 45.4 kg (100 lb) of hide or 1.8 kg (4 lb) of oil and 1.13 kg (2.5 lb) of cake per pulled hide (20% higher on heavily fed cattle and 40% lower on animals in poor condition). The fatty acid composition of the oil is somewhat different from other animal fats and is used in soaps and as an industrial chemical.

Trimming is another critical step in producing quality leather. This can be accomplished before or after fleshing and, therefore, before or after curing. The purpose of trimming a hide is to remove parts of the hide that would have no value as leather and to make the hide conform to what is known as the standard hide trim if the hide is unfleshed, or to conform to the modern hide trim (see Fig. 4.9) if the hide is fleshed. The parts removed from the hide by cutting with a knife include ears, ear butts, snouts, lips, scrotal sac, udders, tail, head skin, fat and muscle tissue from the side of the head and ragged ventral edges.

Sorting of hides after they have been cured in order to fill the tannery's order is usually accomplished on the basis of sex, weight and whether the hide has been branded. Basic categories of hides include: steer hides, both native (unbranded) and branded; heifer hides, both native and branded; cow hides, both native and branded; and bull hides, both native and branded. Branding reduces the value of a hide since the branded area cannot be used in the finished leather product. Bulls produce the thickest hides, are sometimes sold unfleshed and are used for the production of sole leather. Steer and heifer hides tend to be thicker than cow hides, but thinner than bull hides and are often used for shoes and boots. Cow hides are usually the thinnest. Mature bovine hides are used to produce garments, purses and gloves. Hides are also graded for quality and fall into categories No. 1, No. 2 or No. 3 (previously described). The difference in grade is based on number and type of defects. For example, No. 1 hide is of the highest quality, correctly trimmed and free of holes, cuts, deep scores, gouges and other defects. A No. 2 or No. 3 hide contains various degrees of the previously-mentioned defects, as well as others which might include warts or grub damage.

Other damages and defects to the hide listed by Aten *et al.* (1955) and the Marketing Economics Division of USDA (1964) include:

Scratches — caused by thorns, barbed wire, nails and horns and result in grain damage

Branding — results in grain damage but cryo-branding is not as damaging as hot-iron branding

Stick(thorn-)-grass (*Heskaneet cenchrus biflorus*) burr punctures skin and results in grain damage

Mange — caused by many types of mites (*Demodex* spp.) which causes hairless

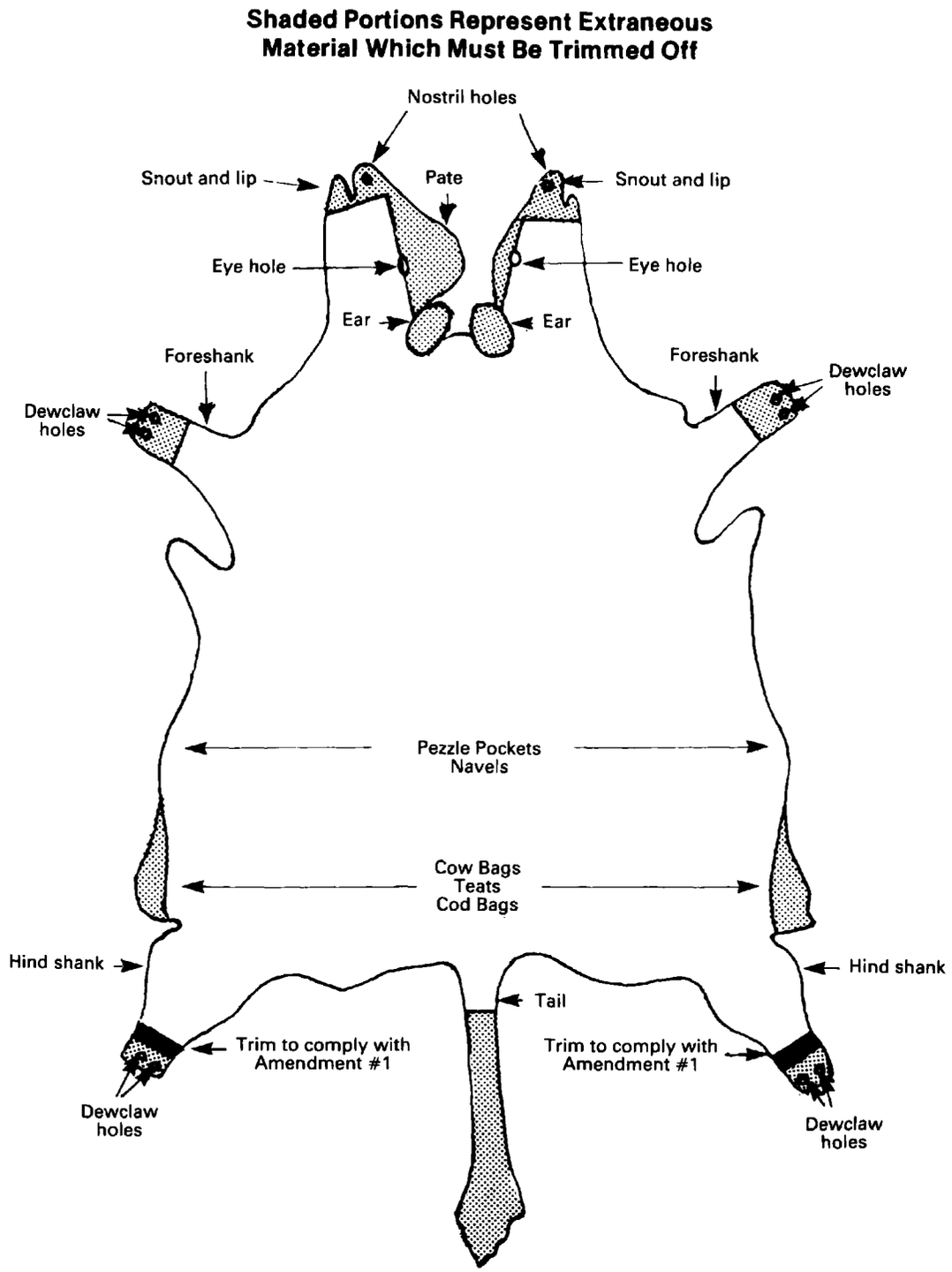


Fig. 4.9 — Modern trim pattern for cattle hide. From United States Hide, Skin and Leather Association (1985).

patches on the skin, thickening of the skin, and the formation of folds, and produce internal voids, grain damage and holes

Scabies — mites cause lesions and the skin thickens and forms folds

Ticks — blood-sucking parasites (*Boophylus* sp., *Hyalomma* sp.) cause holes in leather and white spots on the flesh-side that will not dye; secondary infections also cause leather damage

Lice — biting or sucking parasites that cause scratching, which results in grain damage
Cockle defect — parasite (*Melophagus ovinus*) causes damage to leather
Leeches — aquatic sucking annelids
Warble fly larvae (grubs; *Hypoderma bovis, H. Crossi, H. lineatum*) — make pin-holes in leather
Vertical-fibre defect (pulpy butt) — inherent abnormal vertical orientation of corium fibres which leads to weak leather
Ringworm — fungus causes hair to fall out and plaques are formed which cause grain damage
Cow-pox — infectious disease, usually restricted to skin of the udder and tender areas, which causes dark spots on leather
Hyperkeratosis or X-disease — caused by ingestion of chlorinated naphthalenes, which causes thickening of skin and loss of hair leading to grain damage
Rinderpest — infective virus causes death in susceptible cattle
Trypanosomiasis — parasite of tsetse flies causes this disease that often kills the animal
Streptotrichosis — disease, which causes horny crust on infected skin which results in grain damage
Sweating sickness — tick-born disease, which often causes the animal to rub the skin leading to grain damage
Anthrax — *Bacillus anthracis* spores from this disease cause death of the animals and of hide handlers

Flaying, drying or salt-curing damage (processing damage)
Fouling with blood and dung which causes grain damage
Bruise — blood extravasation in the hide over the bruised area causing grain damage
Inadequate bleeding — blood remains in the hide and encourages bacterial growth
Rubbed or dragged grain
Flay cuts, gouge marks and scores
Bad pattern
Puller or clamp damage ('butcher' or 'grain stretch') — grain damage caused by improper mechanical removal of hide
Improper trim
Chatter damage — parallel gouges caused by improperly maintained fleshing machine
Delay in cleaning, drying or curing — increased putrefaction
Hair slip — bacterial action which causes grain damage to total loss of skin
Overstretching and distortion — most often occurs in dried hides as they contract
Folding — folding of very dry hides may cause them to crack
Incomplete cure — salt has not penetrated the hide
Rotting — insufficient or poor distribution of salt or storage in a warm place with

high humidity that will cause the salt to run off as a brine
Salt stain — dirty or insufficient salt or bacteria
Non-scourable dyes — dyes absorbed by skin and that cannot be removed

Storage and transport damage
Rubbing during transport
Getting wet in transit — causes loss of salt in salt-cured hides and increased moisture for dry-cured hides both of which will result in bacterial growth
Varmint damage — gnawing rodents and varmint manure
Insect damage
Beetle larvae ('woolly bear')
Dermestes maculatus
Dermestes lardarius
White ants

Graded hides are next sprinkled with approximately 454 g (1 lb) of 'safety salt' to insure against deterioration in storage and shipment. Hides are individually folded, flesh-side out, and tied to form a bundle (see Fig. 4.10). The bundled hides are

Fig. 3.10 — Bundling hides. From United States Hide, Skin and Leather Association (1983).

usually tied with different-coloured ropes, or tags may be attached, to identify the type and grade of hide.

The bundles are then stacked on pallets to a maximum height of 107 cm (3½ ft) to squeeze out excess moisture by the weight of the stack. They are then stored in a

warehouse to await shipment (see Fig. 4.11). Before shipment, the hides are weighed and the price per kilogram (or pound) is determined on this weight.

In some countries unsalted hides are chrome-tanned in the slaughter plant to produce what is known as a 'wet blue' moist product. This hide can be stored for months prior to continuation of the leather processing. It saves the cost of salting, and the fleshing material removed from the 'green' (fresh) hide can be rendered into a higher quality product than if the hide had been salted. Other possibilities for eliminating salt curing would be the treatment of hides with sodium sulphite (Na_2SO_3) and acetic acid (CH_3COOH) and holding the hide in a closed system for short-term preservation prior to tanning.

Hides may be shipped by truck, rail or containers on ships, but regardless of the transportation used the vehicle should be inspected for cleanliness and for evidence of larder beetles. These beetles can damage hides in transit and therefore, especially in the summer, the vehicles are usually sprayed with an insecticide before loading the hides. Insecticides are often used to help protect against insect damage. Some of the insecticides often used include:

0.2% white arsenic (As_2O_3, poisonous) with soda or washing soda (Na_2CO_3),
5% sodium silicofluoride (Na_2SiF_6) solution with surface-active agent,
40% sodium silicofluoride powder,
0.5% 1,2,3,4,5,6-hexachlorocyclohexane (Lindane; $C_6H_6Cl_6$),
powdered 1,4-dichlorobenzene ($C_6H_4Cl_2$),
powdered pyrethrum.

Hides are often stacked 1.2–1.5 m (4–5 ft) high in the transportation vehicles.

Hides and skins are often evaluated for quality of cure by determining the moisture (volatile material) and salt (or ash) content of the hide. Moisture is determined by drying at 80°C (176°F) in a vacuum oven for 16 hours, or at 100°C (212°F) in a circulating-air oven for 16 hours. Ash is determined by heating in a furnace at 600°C (1112°F) until a constant weight is obtained. The percentage ratio of ash to moisture is also calculated and this is divided by 35.9 (salt : moisture ratio in saturated brine at 20°C (68°F)) to estimate the percentage of saturation in the brine solution of the hide. Less than 40% moisture indicates excessive dryness causing protein denaturation, which will result in poor quality leather. Hide moisture over 48% indicates excessive wetness and inadequate cure. Even a brine saturation of 85% may not maintain this wet hide during storage.

TANNING

Good reviews of chrome-tanning for the production of leather utilized in making shoes are given in the publication *Leather Facts* (New England Tanners Club, 1983) and a general review of leather production is given in the publication *Leather* (Hague, 1949). Much of the following information is a summary of this material. When the cured hides arrive at the tannery they are taken to and stored in the cooled and well-ventilated tanner's hide house. Here the bundles are open, and the hides retrimmed if necessary and split along the backbone from head to tail to make two

Fig. 4.11 — Bundled hides stored on pallets awaiting shipment to tannery. From United States Hide, Skin and Leather Association (1983).

sides (side of leather). Since tanning is a batch operation, hides are graded and sorted into 'packs' of 2268–4536 kg (5000–10 000 lb) of uniform size, weight and type of hide so that the tanning operation can be adjusted according to the hides involved.

The next step is 'soaking', which restores to the hides moisture that was removed to control bacterial growth during the curing operation. Moisture is needed so that the succeeding tanning operations can be conducted satisfactorily. The soaking of hides is accomplished in half-round cylindrical vats in which the hides are placed with water, wetting agents (detergents) and disinfectants; the hides are stirred in this solution by a dip-paddle wheel similar to the ones used in the raceway curing vats. The stirring action flexes and softens the hide. The soaking usually takes from 8 to 20 hours for the hides to reabsorb the needed water (thicker hides require longer). The last step of soaking is washing the hides by introducing fresh water into one end of the vat and allowing it to exit the other end. This washing removes dirt, manure, salt and blood from the hides.

After washing, the hides are removed from the paddle vat, stacked to drain and, if the hides have not been previously fleshed or if they require additional fleshing, that is accomplished at this point with the fleshing equipment previously described.

If the hide is going to be tanned without hair or wool, the next step in tanning is the 'unhairing' procedure. This was originally accomplished by a process known as 'sweating', in which the hides were placed in a warm, damp room and bacterial enzymes in the skin loosened the hair. Using this process there was always a danger of grain damage and this procedure is no longer widely used commercially except by the wool industry. Acetate (ester of CH_3 COOH) may be sprayed on green skins at pH 4 before incubation at 32°C (90°F) for 20 hours, which will also loosen the wool.

Using current techniques, the keratinous epidermis and some soluble proteins are removed without damaging desirable collagen. The unhairing process is primarily chemical in nature, but there is mechanical unhairing equipment that is sometimes used after the hair has been chemically loosened. The most common chemical depilatory agents are a saturated solution of calcium hydroxide ($Ca(OH)_2$; hydrated lime which loosens the base of the hair follicles) and sodium sulphide (NaS, which will dissolve the hair) or sodium sulphydrate (NaHS). Other mixtures used to remove hair might include milk of lime (CaO; made by mixing 1.8 kg (4 lb) of hydrated lime in 15.1 l (4 gallons) of water) fortified with sodium sulphide (NaS), sodium sulphydrate (NaHS), arsenic sulphide (As_2S_2) or dimethylamine ($(CH_3)_2NH$). And still others use 30% water, 6–12% (of hide weight) sodium sulphide, 2–3% sodium sulphydrate and 4% hydrated lime. Dimethylamine sulphate is also often used as an adjunct to unhairing processes and allows for the reduction of lime and sulphide concentrations. These unhairing agents are mixed with water and, along with the hides, are placed in the previously described paddle vats or mixers (see Fig. 4.12) similar to the types used for some curing. The depilatory concentration,

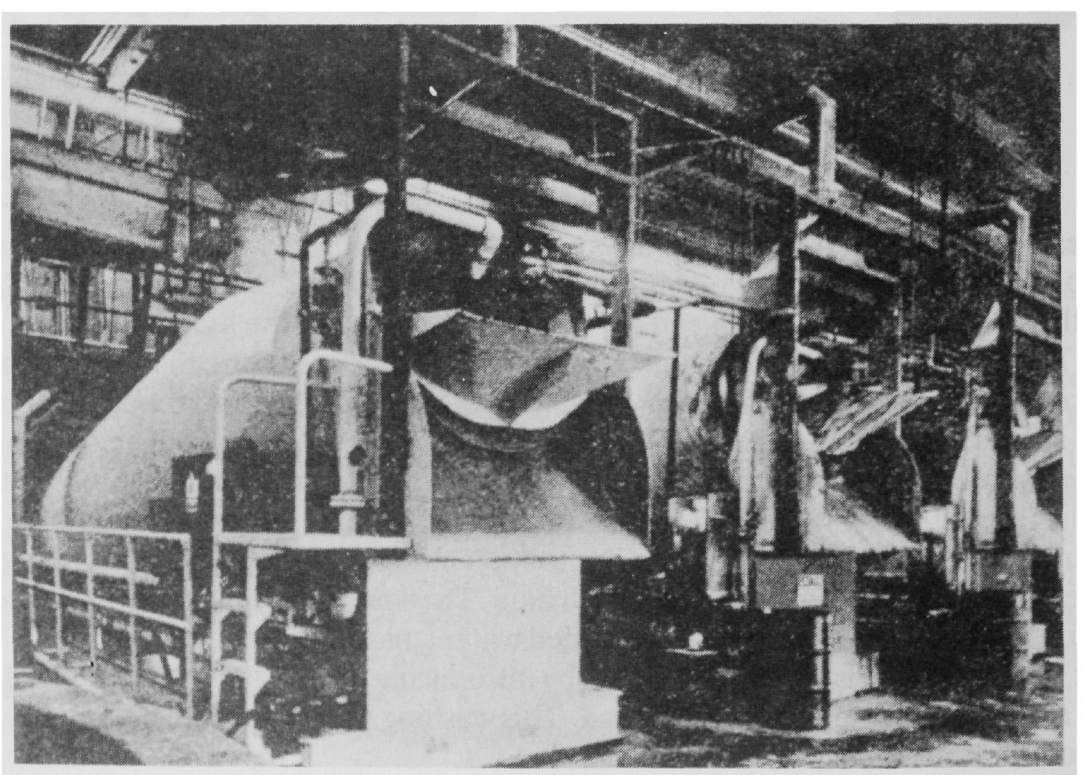


Fig. 4.12 — Mixers used for soaking and unhairing of hides are similar to the mixers used in curing. From New England Tanners Club (1983).

the temperature and the amount of agitation determine the extent and rate of hair removal. If the hair is to be saved, a weak solution and a low temperature are used and only the hair roots are loosened. In two to four days the hair is collected, washed in water, rewashed in water (100 parts) with acetic acid (1 part) and dried. It is sold for a binder in plaster and can be used as insulating material and is used to make hair

felts, carpets, blankets and other other types of textiles. If more concentrated solutions, a higher pH (greater than 11.5) and higher temperatures are used, the hair may be totally dissolved in a few hours. Pigskins require larger concentrations (4–5%) of sulphide than cattle hides for hair removal. If all of the hair is not removed by the chemical reaction, the remaining hair may be removed in an unhairing machine. This was formerly accomplished by placing the hide over a convex wooden 'beam' and manually scraping ('scudding') the hair and remaining material from the hair follicles, but today almost all hair removal is accomplished with a mechanical unhairing machine. This machine operates very much like a fleshing machine except the blades are blunt and produce more of a rubbing than a cutting action. Since the lime–sulphide solution has a high pH, the hides tend to swell ('alkaline swelling') to approximately twice their normal thickness during the unhairing operation, which allows more rapid penetration of other tanning materials.

Unhairing and dewoolling can also be accomplished by enzymes. Again, the speed of hair-loosening increases with the concentration of the enzymes and the temperature. This technique has the advantage that the hair comes out by the roots and yields more hair and a cleaner grain pelt. Pelt scraps containing wool can also be salvaged by enzyme preparations, or acid digestion or bacterial digestion techniques under aerobic conditions that will dissolve the skin completely, leaving the wool undamaged so that it can be salvaged. There is also a slipemaster machine which shrinks the fresh or green skin and plucks the wool with squeeze rollers. One advantage of this technique is that the skin scrap pieces now can be rendered. It should be noted that rendering of skin with wool results in meat meal with indigestible wool fibres. Wool can be hydrolysed at 148°C (298°F), 3.52 kg/cm^2 (50 psi) for 30 minutes to produce a digestible nutritional powder. Wool removed from skin (907 g to 3.6 kg/head (2–8 lb/head)) contributes approximately one-seventh of the wool produced in the U.S.

Some leather is tanned with the hair or wool remaining on the hide. An example would be shearling leather which is produced from sheepskins with uniformly clipped short lengths of wool remaining. This type of product can be tanned by either the chrome or vegetable process, but certain precautions must be considered. First, the wool must be cleaned and degreased by warm soap solutions. Weaker tanning solutions for longer lengths of time are used to keep from discolouring the wool. Dyeing of the wool is much more complicated since wool will not readily absorb most dyes. Often an agent is used that will combine with the wool and then, subsequently, will combine with the dye (called 'mordanting'). Also fat-liquoring is usually done by hand to keep the wool from becoming dirty with the oil. In the final step the wool is clipped to the desired length and 'corded' (separation of the fibres to make them fluff).

Some hides such as kidskins, sheepskins and pigskins contain a large quantity of natural fat (see Table 4.11) and it is often desirable to reduce this to approximately 3% on a dry-weight basis. Skin grease is found in the basal layer of the epidermis, in the sebaceous glands of the papillary layer of the hide as well as the fat cells located between the hide fibres. If these fat levels are not reduced, variation in penetration of tanning ingredients will occur and a uniform leather will not be produced. 'Degreasing' is sometimes done by warming the hides in water and pressing them on a hydraulic press, followed by washing and rinsing. In some cases the skins are washed

with surface active or emulsifying agents (i.e. quaternary ammonium salts of higher fatty alcohols) to aid in fat removal prior to continuation of the tanning process. After this stage the hides or skins are called pelts.

The next process in the tanning operation is 'bating', which removes the alkaline (pH approximately 12.5) unhairing chemicals and other non-leather substances in the pelt structure. The first bating step is 'deliming' which takes place in large wooden drums (see Fig. 4.13), which are rotated on hollow axles. These drums are

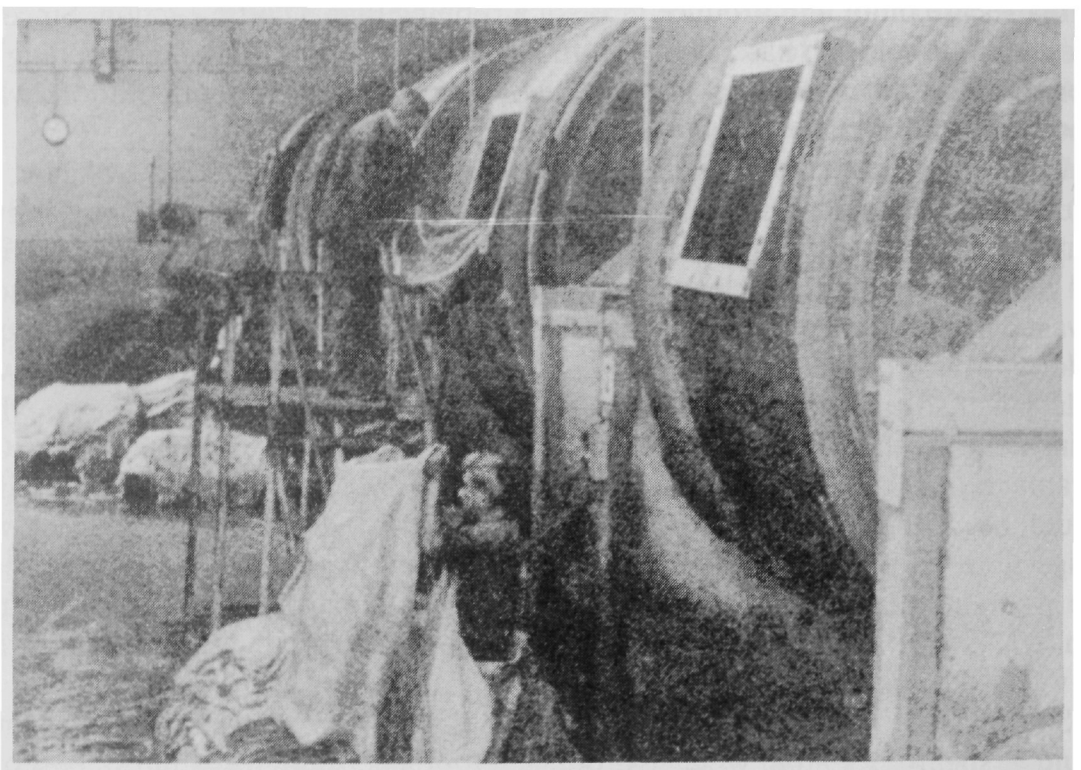


Fig. 4.13 — Drums that may be used for bating, pickling, tanning, retanning, colouring and fatliquoring operations. From New England Tanners Club (1983).

used in several tanning operations and turn at the approximate rate of 16 rpm. The drum also contains a removable door. The deliming consists first of a washing step in which water is pumped into the drum through the hollow axle and is allowed to escape through a perforated door that has been installed in place of the solid door. Salts such as ammonium sulphate $[(NH_4)_2SO_4]$ or ammonium chloride (NH_4Cl) and sometimes trisodium phosphate (Na_3PO_4) or sulphuric acid (H_2SO_4) are then added to convert the remaining lime into soluble compounds which can be removed by washing. If the tanner has stringent ammonia nitrogen controls on waste water then magnesium sulphate $(MgSO_4)$ may be used as an alternative buffer. Ammonium chloride penetrates faster than the corresponding sulphate and results in a softer leather. Ammonium sulphate is used for most shoe-upper leather since it will produce a firmer leather with more temper. These deliming operations lower the pH of 10–13 for limed pelts to approximately 8–9, the alkaline swelling of the

hide is reduced and the pH is in the appropriate range for the enzymatic bates to function.

Bates are enzymes similar to the ones found in the digestive system and are used to digest the remaining components of the pelt that are undesirable for leather manufacturing, such as hair roots and pigments in the grain (outer) side of the pelt. The bates digest and dissolve the non-collagenous protein consistuent of the animal skin and are inactive on collagen, the essential constitutent of leather. Bates for 'puering' (dog-manuring procedure) were originally warm infusions of manure that were allowed to ferment, but this mixture was frequently contaminated with bacteria which damaged the hides. Later, it was learned that a combination of ammonium salts and enzymes produced by bacteria in dung was a useful bating material. The next development in bating material was the use of ammonium chloride (NH_4Cl) and an enzyme extracted from animal pancreas or another extracted from wood. Trypsin has been isolated and found to be a proteolytic enzyme which digests the denatured protein in an alkaline solution. Today, bates are enzymes of bacteria, fungi and plant (often brans) and animal organs. Bating makes the hide softer, less harsh and cleaner. The bate also removes the glue-like material between the collagen fibres that, if allowed to remain, would result in hard and 'tinny-like' leather. There are two theories of how bating works; the first is based on the removal of elastin and other degraded proteins, and the second is based on changes in the collagenous or leather-making fibres. The speed of the bating operation again depends on enzyme concentration, temperature (27–38°C (80–100°F)), pH (8–9) and may last from a few hours to 16 hours, depending on the aforementioned factors and the type of hide. A strong bating action is used in making soft glove leather and a light bating action would be used in making less flexible sole leather. In overnight bating, bacterial growth may become a problem so antiseptics, such as sodium fluoride (NaF), sodium pentachlorophenol (Na salt of C_6HCl_5O) or beta naphthol ($C_{10}H_8O$) are sometimes added at this stage. Many bates are a mixture of deliming materials and various enzymes so that deliming and bating can be conducted somewhat simultaneously. After the bating operation is completed, the pelts are again rewashed to remove the undesirable, digested, non-leather-making material.

The next step is 'pickling', which places the pelts in an acid (pH of less than 3). The hides need to have a low pH in order to accept the tanning materials (e.g. chrome) which are not soluble in an alkaline environment. Sulphuric acid (H_2SO_4) is the most common acid employed but many acids could be used for this purpose. The first step of the pickling procedure is to add salt. Sodium chloride (NaCl) is commonly used but other salts will also function satisfactorily. This prevents swelling ('acid swelling') of the pelts by tying up excess moisture. After the salt is added, acid is introduced into the rotating drums (see Fig. 4.13) and it takes only a few hours for the pickling material to penetrate the pelt. Since the pickling operation is also a preserving step, the pelts could be stored at this step for a considerable length of time without deteriorating. In some countries, predominantly with sheepskins, all of the operations to this point are accomplished at the slaughter plant and the skins are then shipped to the tannery to be converted into leather. The pickling process may be skipped if the pelts are to be tanned immediately after bating and not stored or transported.

The next step in tanning converts the collagen fibres of the skin into a stable non-

putrescible leather. This leather has many desirable properties such as dimensional stability, abrasion resistance, chemical resistance, heat resistance, the ability to flex and the ability to withstand repeated cycles of wetting and drying.

Chrome tanning is the most popular method of tanning today because it can be accomplished quickly and because it produces a leather with desirable physical and chemical properties (long-wearing and heat-resistant). Disposal of chrome is somewhat of a problem since it is considered a toxic waste. If the hides have been stored after pickling they are again placed in a brine and added to the rotating drums (see Fig. 4.13). The pH is adjusted to 2.8 and the appropriate amount of tanning material is also added to the revolving drum. The chemical state of the tanning chemicals is also important in order to obtain a uniform tanned product. For example, the chromium salt (e.g. sodium bichromate, $Na_2Cr_2O_7$) is reacted with a reducing sugar (maltose, $C_{12}H_{22}O_{11}$) and sulphuric acid (H_2SO_4) which reduces the chromium salt to basic chromic sulphate ($Cr(OH)SO_4$, called chrome). It is then added to the hide in the mixing drum (quantity is often from 1.5 to 3%). A 0.02–0.1% preservative such as a sodium salt of a chlorinated phenol is sometimes also added. The pH of the drum contents is increased ('basification') to 3.4–3.6 by adding sodium bicarbonate ($NaHCO_3$, baking soda) or other alkalis (each will result in its own characteristic influence on grain pattern) which increase the alkalinity and the affinity of the collagen for the chrome. The theory of chrome tanning is that cross-linkage is accomplished by bonding of the various chrome ions with free carboxyl groups in the collagen side-chains. The liming aids by exposing additional carboxyl groups by chemical hydrolysis of amine side-chains.

Too little basification will not fix the chrome or will not sufficiently raise the shrink temperature and over-basification will result in a coarse grain. The tanning operation requires 4–6 hours (longer for thicker hides). The rate of tanning can be followed by the wet shrinkage temperature of the hide as well as other chemical tests. For example, an untanned hide will shrink noticeably at 60°C (140°F) but a fully chrome-tanned hide will not shrink at 100°C (212°F) in a bath of boiling water. After tanning, the blue-green hides are transferred to large boxes with holes that will permit excess liquid to drain from the skins. Hides at this point are said to be 'in the blue'.

Vegetable tanning (discussed under re-tanning) is a slower process which takes several months and produces a firmer leather with more water resistance. Vegetable tanning is usually accomplished in a series of vats (first the rocker-section vats to agitate the liquor and second the lay-away vats with no agitation) containing an ever stronger solution of tanning liquor.

Zirconium (an element found in beach sand) can be processed into ZrO_2 and, along with silica and under acidic (pH less than 2) conditions, can tan skin quite rapidly.

A small percentage of skins are tanned by the alum (aluminum potassium sulphate, $AlK(SO_4)_2$) process, sometimes called 'tawing' process to obtain pure white or sole-grey leather, for example, baseball leather and furs. The oil method using fish oil (cod, whale, seal or shark), is often used to produce soft leather for moccasin or chamois leather. The formaldehyde procedure (formalin solution used to tan a white and washable leather); the glutaraldehyde method (for producing

light-tan washable shearling bed pads); the calgon (5% sodium hexamethaphosphate at a pH of 2.8) tanning procedure; the quinone technique; the tungsten tanning procedure; the aluminum method; the iron technique and the silica procedure are other tanning methods. Alum tanning has also been suggested as a substitute for salt curing of green hides because it offers a great deal of control over the re-tanning operation by the tannery.

The next procedure in producing leather is 'wringing' or 'setting', sometimes called 'sammy', whose purpose is to remove excess moisture, smooth the grain and remove wrinkles from the hide. The machine that accomplishes this is similar to the previously described wringing machine, and the operation consists of passing the hide between two large rollers. In addition to removing moisture this operation slightly compresses the hide, but it soon returns to its normal thickness. Over wringing, however, will make the leather too thin and will reduce the moisture to the extent that excessive drying may occur.

After wringing, the next two operations are 'splitting' and 'shaving' and the purpose of these operations is to adjust the leather thickness (one iron=0.53 mm ($\frac{1}{48}$ in) or one ounce=0.40 mm ($\frac{1}{64}$ in)) to that desired for its ultimate use. Hide thickness can vary from animal to animal due to such things as age, and can also vary from different areas of the skin on the same animal. The major portion of the thickness adjustment is accomplished by splitting. The splitting is carried out on a horizontal band-saw which contains a sharp flexible knife instead of saw teeth. The hide is fed through the machine with the grain (outer) portion up and this is the portion that is sized. Adjustable feed rolls above and below the knife control the ultimate thickness of the grain side of the hide to 0.25 mm ($\frac{1}{100}$ in). The underside (flesh layer) is called a 'split' (does not contain any grain) and it is often thick enough to be used for suede types of leathers. These splits are sometimes further processed by specialized tanners. The split can also be used as a raw material for manufacturing collagen sausage casings.

The grain portions of the hides are then shaved, which requires passing these through a type of fleshing machine with helix shaped cutting blades. In splitting, some areas of the hide may not have been thick enough to come into contact with the splitting blade and the shaving operation is used to cleanse such areas of any fleshy material and also to further adjust the overall uniformity of thickness of the hide.

Often the hides are now 're-tanned', using the combined desirable properties of more than one tanning agent. The more popular re-tanning agents are vegetable extracts and syntans. The vegetable extracts are some of the originally used tanning agents and are extracted from trees and shrubs with water and heat. The commercial tan bark is the shredded spent bark. This tan bark is used in animal show rings or as a fertilizer. Tannin (tannic acid, $C_{76}H_{52}O_{46}$) is the active tanning agent in vegetable extracts and it is found in over 300 species of plant life, but less than 20 are normally used. Some of the more common vegetable sources would include:

Chestnut (olive-brown leather)
Chinese nutgall
Cutch (deep-red leather)
Divi-divi
Eucalyptus

Table 4.16 — Pit -curing of fleshed hides, requiring a minimum of 3 days and yielding 62–68% of green hide weight

Weight (lb) hides	Operation or activity	Composition[a] or change
Green		
100	Receive hides from slaughter	65–70% water, 30–35% hides
100	Trim ears, snout and tail	3% loss; 3 lb trim to rendering
97	Wash hides	2% loss; 2 lb blood and manure
95	Flesh and demanure with machine	12–18% loss, 12–15 lb fleshing to rendering, 1–3 lb manure
80	Trim pattern	3–4% loss, 3 lb trimming to rendering
77	Salt hides down into pit (122–152 cm (4–5 feet) deep), flood with saturated brine	0.5 lb of salt (No. 1 rock salt) per 1 lb of hide
77	Cure in pit (still brine) for 48–55 hours, drain pit for 24–33 hours	15–17% net loss in weight; 20–25 lb loss in water, 7–11 lb uptake of salt, 10–15 lb loss of salt to sewer[b]
Cured		
65	Remove for pit, inspect, bundle	Reclaim excess salt
65	Move hides to storage or load for shipment	12–16% salt, 35–45% water, 40–50% hide substance

[a]Multiply pounds by 0.454 to convert to kilograms.
[b]Most modern processors in 1987 recycle excess brine and do not discharge it. Also the use of evaporation ponds decreases discharge to sewers.
Biedermann *et al.* (1962), Minnoch and Minnoch (1979).

Gambier (yellow leather)
Hemlock
Mangrove
Mimosa
Myrobalan
Oak
Palmetto root
Quebracho (red leather)
Spruce
Sumac
Turkish nutgall
Valonia (buff-coloured leather)
Wattle

Vegetable tannins are polyphenolic compounds of two types. The hydrolysable tannins (i.e. chestnut and myrobalan) are derivatives of pyrogallols, and the condensed tannins (i.e. hemlock and wattle) are derivatives of catechol. Vegetable tanning probably results from hydrogen bonding between the tannin phenolic groups and the peptide bonds of the protein chains. In some cases as much as 50% by weight of tannin is incorporated into the hide.

The vegetable re-tanning results in solidity, body, and more uniformity in chrome-tanned leather. This is very important in pigskins to modify the difference in temper of various parts of the skin.

Syntans are man-made chemicals generally produced by condensing aromatic sulphonic acids or phenols with formaldehyde; syntans can also be of the acrylic resin type. Syntans are used to produce softer-type leather and also to produce white or pastel shades since the syntan will have a bleaching effect on the blue-green chrome-tanned leather.

For re-tanning the hides are placed again in the rotary drums (see Fig. 4.13). Here they are washed and neutralized with mild alkali to adjust the pH to the most appropriate level for the re-tanning material selected (i.e. pH 5 for vegetable tanning). Then the re-tanning agent is added and re-tanning usually takes approximately 1–2 hours.

The next step is often 'dyeing' of the leather to produce the desired colour. Proper dyeing is still somewhat of an art-form since pigskin colour uptake is different from that of cattle hide, and most leather material has non-uniform pigmentation and grain structure although a fairly uniform colour is often desirable; however, some slight non-uniformity is often wanted since this is very difficult to duplicate in synthetic material. There are hundreds of different dyestuffs and auxiliary products, and usually leather is dyed with blends to achieve the desired colour. The penetration depth and exhaust rate of the dye blends are important since the blends must work together to produce the desired results. Again the tanner makes use of pH control to effect the affinity of the dyestuff for the fibres.

Categories of dyes used:

acid-dyes — penetrate readily, bright colours,
aniline types — combine with skin fibres,
basic dyes — surface dyeing, brilliant shades,
direct dyes — surface dyeing, deep shades,
metallized dyes — level dyeing, subdued colours.

The aim of colouring is not only to produce the right strength (contraction) and shade (hue or dullness) of colour but to produce a colour that will resist fading, that will not bleed, and that can be dry-cleaned or washed.

After colouring, the hides are washed to eliminate residual dyestuff, to adjust the pH and the temperature (usually to 52°C (125°F)) and the next step is 'fatliquoring', which is used to adjust the firmness or softness of the leather by lubricating the fibres. Fatliquoring may also increase the tensile strength of the leather. The basic

ingredients ('sponging' compounds) of fatliquoring are vegetable, fish, mineral or animal oils, such as Neat's-foot oil, glycerin and related fatty substances, soaps, egg yolk, and sometimes waxes or clay and chemical reagents that will react with the oils to improve their water solubility or emulsifiers which will disperse the non-polar oils in a stable emulsion. Other materials that might also be added would include: powdered lignin, naphthalene syntan, Epsom salts, corn sugar, salts of organic acids, bicarbonates and borax. Some fatliqouring materials are highly sulphated oil blends to make them more water-miscible. Anionic fatliquors are prepared from mixtures of either sulphated or sulphonated oil with raw oils. Cationic fatliquors are blends of alkylated long-chain amines mixed with raw oils. The fatliquoring operation usually requires approximately one hour at elevated temperatures in the rotating drum (see Fig. 4.13). By selecting the type and amount of fatliquor, various degrees of softness can be achieved from the same type of tanned leather. Pigskins usually require more fatliquor than cattle skins.

The next process in producing leather is called 'setting out' and its purpose is to smooth and stretch the leather and to compress and squeeze out the excess moisture and grease. This is accomplished on a fleshing-like machine with a blade designed to exert pressure and to smooth the grain. This compresses the leather (which will remain compressed during drying) and results in a product with approximately 60% moisture.

The next step is 'drying', whose purpose is to remove all but equilibrium moisture. There are three different drying methods and the one chosen will have an influence on the characteristics of the final leather.

The simplest drying method is 'hanging', in which the leather is hung like washing and is then often passed through a large drying oven which is maintained below 54°C (130°C) to reduce shrinkage.

Another drying method is called 'toggling'. In this technique the skins are stretched and attached to a metal perforated frame by fastening hooks called toggles. An additional skin is then fastened to the other side of the frame. These frames are then placed in a drying oven.

The popular drying technique is called 'pasting' in which the hides are actually pasted to large stainless steel, porcelainized steel or glass plates. The plates are first washed and dried, sprayed with a paste solution (starch-like material that will cause adhesion of the wet leather but will release the dried leather), the grain side of the leather pressed against the plate, and the leather pressed and smoothed with a dull-bladed instrument called a 'slicker', then the plate is placed in a drying oven 60–66°C (140–150°F), 40% relative humidity for 4–6 hours.

Another drying technique is the use of 'vacuum dryers' which dry the leather under vacuum while it is on a hot stainless steel plate.

After drying the skins should contain 10–12% moisture.

The next operation in leather production is called 'conditioning' or 'wetting back' and it involves the introduction of controlled amounts of moisture. After the leather has been dried it is hard and fairly unworkable and the ultimate user usually requires varying degrees of softness (called 'temper'). The moisture is applied by shower-like nozzles and then the hides are stacked and covered with a moisture-proof material to allow the leather to 'mull' approximately 16 hours during which time capillary action uniformly distributes the moisture. The moisture level is usually raised to approxi-

mately 25%.

The next step in softening and making the leather more pliable is called 'staking' and it, in combination with the previously described fatliquoring, primarily governs the final temper of the product. The staking machine contains jaws that open and close and move back and forth, while the leather is manually moved by the operator, for approximately one minute per hide. The combination of pulling and rolling by the staking machine applies a great deal of mechanical stress and flexes the leather fibres. After staking, the excess moisture is now 'aired-off' by one of the previously described drying methods.

The next process in leather production is 'buffing', which involves smoothing the grain surface by light mechanical sanding to improve the appearance of the leather and to diminish any blemishes that might be present (sometimes the flesh-side is also buffed). The buffers use a sanding drum or belt (Carborundum abrasive paper) with controls to regulate the degree of abrasive cutting. If the leather is not buffed it is called 'full grain'. A lightly buffed leather is called 'corrected grain', intermediate buffing produces 'snuffed leather' and deep buffing gives 'buffed leather'. Leather dust created by the buffing is removed by brushes, jets of air or vacuuming, and dust removers are sometimes incorporated into the buffing equipment.

The next operation is 'finishing' which is the application of film-forming materials that provide abrasion and stain resistance, enhance the colour (finishng material may be from transparent to opaque) and make the leather easy to care for. The type of finish is determined by the type of skin (pigskin is more difficult to finish and frequently requires 30% more finish) and the ultimate use of the leather.

Coating materials include:

Acrylate polymers (basic structure is acrylic acid, $C_3H_4O_2$)
Albumin blood (see albumin egg)
Albumin egg (egg white: 53% C, 7% H, 16% N, 2% S)
Butadiene polymers (basic structure is butadiene, C_4H_6)
Casein (cow's milk protein, 54% C, 7% H, 16% N, 22% O, 1% P, 1% S)
Isinglass (fish glue, see Chapter 5)
Linseed oil (glycerides of linolenic, linoleic, oleic, steric, palmitic and myristic acids)
Nitrocellulose ($C_{12}H_{16}N_4O_{18}$)
Polyurethane (basic structure urethane, $NH_2COOC_2H_5$)
Acrylic–urethane copolymer
Shellac (resinous excretion of an insect)
Vinyl polymers (basic structure vinyl acetate, $C_4H_6O_2$)
Wax (vegetable fat expressed from a fruit)

The equipment for applying finishing material depends upon the product used. A popular machine is the 'seasoning machine', which pumps the finish into a trough where it is picked up by a fluted roll, transferred to a rotary brush, which places it on the leather, and then worked into the leather with mechanical swabs. A heavy coat of finish may be applied with a 'flow coater' which pumps the finish into a reservoir or 'head'. It then flows through a narrow slit in the bottom of the head or it overflows the

head in a thin unbroken sheet onto the leather, which is transported on a conveyor under the head. Another piece of equipment used to apply a light coat of finishing material is a 'rotary spray' which sprays the finish over the conveyerized leather. This equipment can produce multi-tones and unique patterns. Some equipment passes the wet coating under a beam of electrons or ultraviolet light to encourage polymerization.

After the finish is applied it must be dried. A common procedure is to use a long tunnel which may be heated with steam-heated air or infra-red units. Maximum results are obtained when several coats of finish are applied with intermittent drying between applications.

The next processing step is 'platining', which smooths the grain surface or produces a varied grain texture. After platining, another coat of finish may be applied and platining repeated; this cycle may be repeated several times over a 4–5 day period. The platining operation is conducted on presses that exert 25 283 kg pressure per m^2 (300 tons/in^2) at 107°C (225°F) steam-heated temperature and the leather is platined for a few seconds.

The leather may also be embossed at this point by engraved plates which produce a pattern on the leather when pressure is applied; the leather will permanently retain this embossed pattern.

Since leather is sold by the area, the next step is to measure this on the irregularly shaped hide. This is accomplished by a planimeter whose fingers sense the leather as it passes through the machine and sums the total area of the piece of leather.

The final step is 'grading', which determines the quality of the finished leather. It is graded for temper, uniformity of thickness and colour, and defects. The graded sides are grouped into batches of four or five hides, rolled into a bundle, covered with paper; this package is sometimes placed in a wooden box. The time required from hide curing to finished leather production averages four weeks.

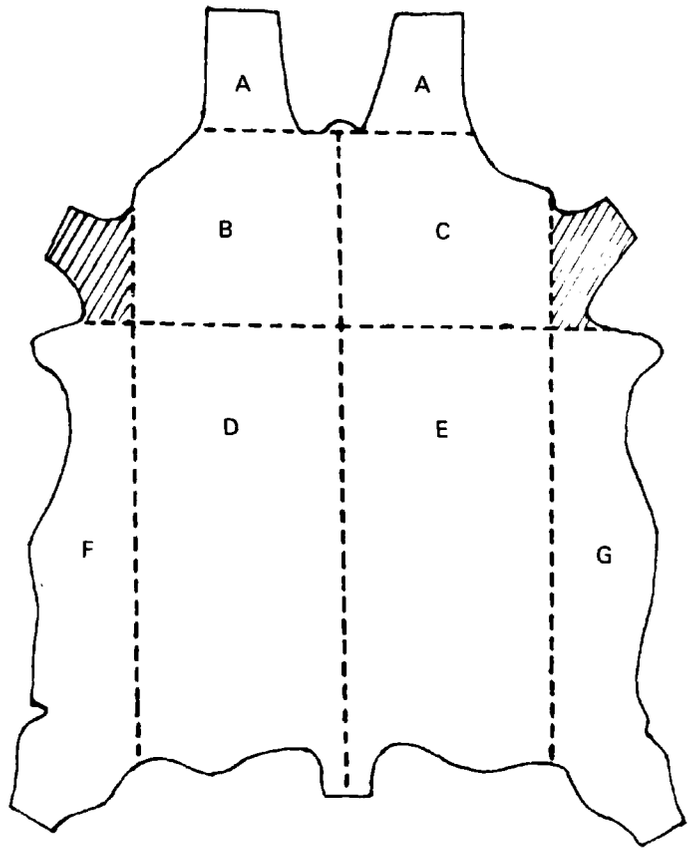
After the processing of most hides from large animals, it is customary to subdivide the hide (see Fig. 4.14) into smaller sections for easier handling; also the various areas of the hide are often better suited for manufacturing different types of leather articles.

PHYSICAL PROPERTIES OF LEATHER

Leather has many unique and valuable physical properties and most of these can be attributed to the internal structure of the leather. A photomicrograph of this structure can be seen in Fig. 4.15. The top portion of this figure is the grain layer (hair– or grain-side), the bottom portion is the flesh-side and the centre section is termed the corium. Notice the twisting, interlocking structure, which has many of the properties of a coiled cable or rope.

Leather has a very high tensile strength (the greatest longitudinal stress a substance can bear without tearing) for a flexible sheet material, as shown in Table 4.17. Leather traditionally has tensile strength values from 140 to 281 kg/cm^2 (2000–4000 psi) which makes it one of the strongest flexible sheet materials known.

Leather also has a very high tear strength (see Table 4.17), which makes it very tear resistant. This is because the fibres are fairly random in orientation and do not



HEAD	A	CROP	A+B+D or A+C+E
SHOULDER	B+C		
BEND	D or E	BACK	B+D or C+E
BELLY	F or G	CROUPON	D+E
SIDE	A+B+D+F or A+C+E+G	DOSSET	B+C+D+E+A or -A
		CULATTA	D+E+F+G

F and G includes shaded area except for culatta

Fig. 4.14 — Subdivisions of a hide. From United States Hide, Skin and Leather Association (1985).

have a fixed path for the tear to follow. This means that leather usually is not hemmed and stitching is not required around a punched hole. Pigskins, however, are much weaker in tear resistance and consequently cannot be used in some products in which they are subject to tear-type stresses. The elongation (maximum extent to which the material can be stretched without breaking) of leather (see Table 4.17) can be controlled from 15 to 73% by selecting the appropriate tanning and fatliquoring processes. Under normal conditions, however, leather is usually subjected to elongation stresses of from 15 to 25%. Leather also has excellent flexibility over a wide temperature and moisture range, making the product uniquely suitable for manufacturing things to be used in harsh environments. Leather also provides an added safety feature due to its puncture resistance (ability to resist penetration by a sharp object). This also contributes to its long-wearing properties. Leather can absorb and transmit moisture, has the ability to breath (pork skin is very good at this), the ability to cool in hot weather and insulate in cold weather, and is windproof, all of which make it ideal material for garments and shoes. Leather also has moulding

Fig. 4.15 — Photomicrograph of leather cross-section which is 1.8 mm ($\frac{1}{16}$ in) in actual thickness. From new England Tanners Club (1983).

Table 4.17 — Physical properties of shoe upper leather

Property	Value
Tensile stength (MPa)[a]	15.3–37.5
Elongation at break (%)	29.5–73.0
Stich tear strength (N/cm)[b]	1280–2275
Thickness (mm)	1.5–2.4
Bursting strength (kN/cm)[b]	1.1–24.5
Apparent density (g/cm^3)	0.6–0.9
Real density (g/cm^3)	1.4–1.6
Heat resistance	Shrinks depending on moisture; anhydrous decomposition at 160–165°C.

[a]To convert MPa to psi, multiply by 145.
[b]To convert N/cm to lbf/ft, divide by 14.6.
United States Military Specification (undated), Wilson (1927), Conabere and Hill (1948), Roddy *et al.* (1948, 1949), Kanagy (1965), Kremen and Lollar (1951), Kizk-Othmer Encyclopedia of Chemical Technology (1981).

ability and retains its other desirable properties even after being permanently deformed into new shapes, which is one of the most significant properties in making shoes. This combination of properties of leather make it a unique material for many uses.

TANNING EFFLUENT

Since curing and tanning remove protein and fat from hides and these processes use large quantities of salt and tanning and processing chemicals, the effluent from tanning operations can be a pollutant; consequently effluent treatment can be a major expense. The quantity of loadings found in waste water for pigskin and cattle-hide processing can be found in Table 4.18.

Table 4.18 — Comparison of waste water loadings and yield

Parameter	Average loading (lb/1000 lb rawstock)[a]	
	Pigskin	Cattle hide (Twenty 50 lb hides) Hides contain 580 lb solids Chemicals added 350 lb solids Total solids 930 lb
Flow (gallons/1000 lb rawstock)[b]	1740±198	1488±350
Total solids (lb)	638±48	438±95
Dissolved solids (lb)	505±38	386±104
Landfill solids (lb)		50
Air-volatile solids (lb)		35
Ammonia (lb)	9±1.1	7±2.5
Oil and grease (lb)	50±19	11±6
Chloride (lb)	108±9	131±28
Total Kjeldahl nitrogen	24±3	16±6
Chemical Oxygen Demand	327±39	102±25
Grain leather, solids (lb)		175
Blue drop, solids (lb)		195
Grain leather)ft^2)[c]		800
Offal (lb)		75

[a] 1 lb=0.454 kg
[b] 1 gallon=3.785 l
[c] 1 ft^2=0.093 m^2
Taylor *et al.* (1982), Diefendorf *et al.* (1983), Lollar (1977).

Some tanners are recycling chromium through precipitation/re-solution procedures, through incineration and extraction, through spent chrome addition to pickle liquors or through extraction of waste water sludges. Other metals in tannery waste such as lead (from finishing pigment), zinc and copper are also a problem.

TANNERY WASTE

Solid waste (from trimming, cutting, fleshing and shaving hair and buffing material) or tannery offal is used as fertilizer, feed, for glue/gelatin, hair, grease and leather board. The tannery solid waste contains two proteins; keratins from hair and collagenous hide fibres. These proteins are normally hydrolysed to produce swine and poultry feed. The percentage of tannery offals that may be utilized in animal diets is normally limited due to the unbalanced amino acid composition and high ash content. Fibred leather or leatherboard, insulation and acoustic building tiles may be made from leather shavings and trimmings. 'Shoddy' leather is made by converting waste leather to a pulp and pressing it into sheets, either with or without a binding material.

Incineration is another technique used to dispose of tannery offal. Chrome in the blue-leather state has a heating value of 1966 kcal (7800 Btu) per 453 g (1 lb) of dry matter. Incineration ash can be further processed for chrome recovery. Pyrolysis (400°C (752°F) with a deficiency of oxygen) of leather waste along with catalysts will yield a granular material that may be used like activated carbon.

REFERENCES

Aten, A., Innis, R. F. and Knew, E. (1955) *Flaying and curing of hides and skins as a rural industry.* Rome, Food and Agricultural Organization of the United Nations.

Conabere, G. O. and Hill, R. A. (1948) in *Progress in leather science.* London, British Leather Manufacturers' Research Association. pp. 1920–1945.

Bengtsson, O. and Holmqvist, O. (1984) *By-products from slaughtering.* Fleischwirtschaft **64**(3) 334–336.

Bidermann, K., Neck. H., Neher, M.B. and Wilhelmy, Jr. V. (1962) *A technical–economic evaluation of four hide curing methods.* Argicultural Economic Report No. 16., Washington, Marketing Economics Division, Economic Research Service, USDA.

Clemen, R. A. (1927) *By-products in the packing industry.* Chicago. University of Chicago Press.

Diefendorf, E. J., Taylor, M. M., Bailey, D. G. and Feairheller, S. H. (1983) *Pigskin processing with short floats.* JALCA 78: 156–166.

Hague, H. M. (1949) *Leather.* Tanners' Council of America, Washington D.C.

Henrickson, R. L., Turgut, H. and Rao, B. R. (1984) *Hide protein as a food additive.* JALCA 79: 132–145.

Judge, M. D., Salm, C. P. and Okos, R. M. (1978) *Hog skinning versus scalding.* American Meat Institute Foundation, Arlington, Va., Meat Industry Research Conference. pp. 155–164.

Kanagy, J. R. (1965) referenced in *The chemistry and technology of leather.* Vol. IV, edited by O'Flaherty, F. Roddy, W. T. and Lollar, R. M., New York, Reinhold Publishing Corporation. pp. 369–416.

Kirk-Othmer Encyclopedia of Chemical Technology (1981) *Kirk-Othmer encyclopedia of chemical technology.* Third Edition, Vol. 14, New York, John Wiley. pp. 200–230.

Kremen, S. S. and Lollar, R. M. (1951) *J. Am. Leather Assoc.* **46**, 34.

Lawrie, R. (1981) *Developments in meat science — 2.* London, Applied Science Publishers.

Leather Industries of America (1987) *U.S. Leather Industry Statistics.* Washington D.C., Leather Industries of America.

Leather Industries of America and U.S. Hide, Skin and Leather Association (1985) *Trade practices for proper cattlehide delivery.* Washington D.C., Leather Industries of America and U.S. Hide Skin and Leather Association.

Lollar, R. M. (1977) *A technical assessment of our leather industry: challenges and opportunities in the late 70's. JALCA* **27** 254–269.

Marketing Economics Division, USDA (1964) *A guide to lower cost and greater efficiency in curing cattle hides.* Agricultural Economic Report No. 54, Washington, D.C. Marketing Economics Division, Economics Research Service, USDA.

Minnoch, J. J. and Minnoch, S. R. (1979) *Hides and skins,* 3rd edn. Prepared by Education Committee (E. A. Whitney, Chairman) Sioux City, Iowa, National Hide Association.

Moulton, C. R. and Lewis, W. L. (1940) *Meat through the microscope,* revised edition. Chicago, Institute of Meat Packing, The University of Chicago.

National Hide Association, (1979) *Hides and skins.* Sioux City, Iowa, National hide Association.

New England Tanners Club (1983) *Leather facts.* 2nd edn. Peabody, Massachusetts, New England Tanners Club.

Ockerman, H. W. (1983) *Chemistry of meat tissue.* Columbus, Department of Animal Science, Ohio State University.

Price, J. F. and Schweigert, B. S. (1971) *The science of meat and meat products.* San Francisco, W. H. Freeman.

Roddy, W. T., Echerlin, R. and Jansing, J. (1948) *Quartermaster general's research reports on leather technology.* April 15. Washington D.C.

Roddy, W. T., Jacobs, J. and Jansing, J. (1949) The water resistance and other physical and chemical characteristics of an army upper leather. *J. Am. Leather Assoc.* **44** 308.

Romans, J. R. and Ziegler, P. T. (1974) *The meat we eat.* Danville, Illinois, Interstate.

Tanners' Council of America, (1972) *Trade practices for proper cattlehide delivery.* Washington D.C., Tanners Council of America.

Tanners' Council of America (1983) *Dictionary of leather terminology.* Washington D.C., Tanners Council of America.

Taylor, M. M., Diefendorf, E. J., Hannigan, M. V., Bailey, D. G. and Feairheller, S. H. (1982) *The leather manufacturer* **100**(1) 20.

U.S. Department of Agriculture (1987) *Leather Industries of America.* Washington, D.C., USDA.

U.S. Department of Commerce (1987a) *Footwear Retailers of America.* Washington, D.C., United States Department of Commerce.

U.S. Department of Commerce (1987b) *U.S. industrial outlook for 1984.* Washington, D.C., United States Department of Commerce.

United States Hide, Skin and Leather Association, (1983) *Modern cattlehide procedures — a slide set.* Washington, United States Hide Skin and Leather Association.

United States Hide, Skin and Leather Association, (1985) *Trade practices for proper packer cattlehide delivery.* Washington, United States Hide, Skin and Leather Association.

United States Hide, Skin and Leather Association (1987) *Letter to the membership.* Washington, United States Hide, Skin and Leather Association, Feb., pp. 1–8.

United States Military Specification (undated) MIL-L-3122.

Wilson, J. A. (1927) *International critical tables of numerical data, physics, chemistry and technology.* New York, McGraw-Hill. pp. 250–254.

5

Glue and gelatine

INTRODUCTION

Glue and gelatine are both water-soluble, hydrophilic, derived colloidal proteins (albuminoids) produced by controlled hydrolysis of water-insoluble collagen (white fibrous connective tissue). Glue and gelatine are physically and chemically similar. The major difference is that gelatine is made from fresh, federally (in U.S.) inspected raw materials in a sanitary manner which allows the product to remain in an edible condition (see Table 5.1).

Collagen (anhydride of gelatine) is composed of tropocollagen monomers arranged in overlapping fibrils that are configurated in three non-identical coiled peptide chains. The number and type of chemical covalent cross-bonds between these chains are altered as the animal ages (fewer number in younger animals). This influences the molecular properties of the resultant gelatine or glue.

The conversion of tropocollagen to gelatine or glue involves the breaking of hydrogen bonds which stabilize the triple-coil helix and transforming it into the 'random coil' configuration of gelatin or glue. The hydrolysed product depends upon the cross links which remain between the peptide chains and reactive amino- and carboxyl-terminal groups that have been formed. Since the three chains are not identical, three basic types of new chains result after cleavage: the alpha-chain consisting of one peptide chain, the beta-chain made of two peptide chains still connected and the gamma-chain consisting of three connected peptide chains; therefore a single gelatine sample has several molecular weights. The molecular-weight distribution of gelatine determines its characteristics, such as colloidal dispersion in water, viscosity, adhesiveness and gel strength. Larger relative concentrations of low molecular-weight molecules will lower viscosity and cause the product to have a lower gel strength. This condition is usually caused by high temperatures and/or highly acidic or alkaline conditions, but can also be caused by the type of raw materials and the liming time.

Gelatine is a derived protein of the albuminoid class in contrast to natural gums which have some of the same physical properties, but are polysaccharides in nature and have a completely different chemical composition. For example, agar-agar also

Table 5.1 — Terminology in the glue and gelatine area

Term	Types	Definition	Use
Glue	Hide, bone, blood albumin (water resistant)	Crude form of gelatine	Adhesive in plywood, furniture, veneer, paper board, match heads to give an air-tight cap over phosphorus, paper sizing, sizing walls before painting, sizing barrels or casks that are to contain liquid, in manufacture of wool, silk and other fabrics, sand and emery paper, composition cork, imitation hard rubber, printing rolls, mother-of-pearl, gummed tape, paper boxes and book binding.
Gelatin (spelling contains no e)		Pure protein from collagen	
Gelatine	Hide, bone	Purer and cleaner form	Used in food (ice cream, mayonnaise dressing, emulsion flavours), to clarify wine, beer, and vinegar, pharmaceuticals (capsules and coating for pills), photography, sometimes an adhesive, electroplating, bacteria culture medium.
Ossein		Demineralized bone, spongy undissolved matrix of collagen	A very desirable raw material for the extraction of gelatine
Isinglass		Gelatine obtained from fish bladder	Good source of gelatine

forms a gel but is a sulphuric acid ester of a range of polysaccharides obtained from seaweed. Other seaweed extracts would include Japanese gelatin or Japanese isinglass (vegetable agar), Chinese Moss, and Irish Moss. Pectin also has gel-forming properties but is obtained from fruit. Another product sometimes confused with gelatine is gelatine explosive (blasting gelatine) which is a mixture of nitroglycerine and diatomaceous earth. It is not related to animal gelatine.

Collagen and gelatine or glue, from a nutritional standpoint, are composed of long chains of amino acids connected by peptide bonds; the amino acids contain both acid and basic functional groups. The amino acid composition (see Table 5.2) of collagen and consequently gelatine and glue is almost completely lacking in tryptophan and is low in methionine, cystine and tyrosine. It is therefore not a complete protein from a nutritional standpoint because it will not supply the total daily requirement of 'essential' amino acids (amino acids that cannot be synthesized by the body in sufficient quantities and must be regularly ingested as food). However, if used in a 'normal' diet with other proteins, gelatine will in some cases increase the biological value of the added protein. Under these combined-protein conditions, gelatine makes a very acceptable protein source provided it is not used as the only source of protein. When a sugar substitute is used with gelatine, the tasty and filling gelatine desserts make a good diet food because they require more calories to digest than they contain (specific dynamic action principle). Gelatine is often used as a therapeutic agent in such areas as infant feeding, and for patients with digestive problems, peptic ulcers, muscular disorders and to encourage nail growth. Unlike other proteins collagen has a fairly high content of the amino acids proline and hydroxyproline. The quantity of these amino acids is often used as an index of the quantity of collagen in a protein mixture.

RAW MATERIALS

Since collagen is 30% of the animal body's total organic matter, or 60% of the animal body's protein, it is obvious that many tissues could be extracted for glue and gelatine. A listing of possible raw materials can be located in Table 5.3 and the yield that can be expected may be found in Table 5.4. The tissues with fairly large quantities of collagen that are commercially available as a by-product, however, are usually hides or skins (including pig skins) and bones. The other sources, even though feasible, are usually utilized only in small quantities. Contrary to popular opinion, hoofs, horns, hair, feathers and egg-shell waste do not yield gelatine.

MANUFACTURING OF GLUE AND GELATINE

The object of glue and gelatine manufacturing is to control the hydrolysis of collagen (from various sources) and to convert the resulting product into a soluble material with desirable physical and chemical properties, such as gel strength, adhesiveness, colour, tack and clarity. Essentially the process consists of three major steps: (1) removal of non-collagenous compounds from the new material with as little alteration to the collagen as possible, (2) controlled hydrolysis of collagen to gelatine and (3) the recovery and drying of the finished product (see Fig. 5.1). All of these steps and the starting raw material will influence the quality and yield of the finished product. Controlled hydrolysis is needed to convert collagen (molecular weight range from 345 000 to 360 000) to gelatine (molecular weight range from 10 000 to 65 000 and in a few cases up to 250 000), but continued hydrolysis will result in loss of yield and loss of desirable properties. Also the nature and condition of the raw material can greatly influence the final extracted product. This can vary not only

Table 5.2 — Amino acid composition of collagen and gelatine

Amino acid	Number of residues/ 100 residues			Percentage by weight			
	Hide	Ossein	Pigskin	Type B skin	Type B bone	Type A porskin	Mixed gelatin
Alanine	10.1–11.0	11.0	11.1	9.3–11.0	11.3	8.6–10.7	11.0
Arginine	4.5–4.6	4.9	4.8	8.5–8.8	9.0	8.3–9.1	8.8
Aspartic acid	4.9–4.4	5.0	4.7	6.6–6.9	6.7	6.2–6.7	6.7
Cystine	—	—	—	Trace	Trace	0.1	Trace
Glutamic acid	7.1–7.2	7.6	7.2	11.1–11.4	11.6	11.3–11.7	11.4
Glycine	33.5–33.8	31.4	32.6	26.9–27.5	27.2	26.4–30.5	27.5
Histidine	0.43–0.45	0.58	0.60	0.7–0.8	0.7	0.8–1.0	0.78
Hydroxylsine	0.63–0.66	0.64	0.59	0.9–1.2	0.8	1.0	—
Hydroxyproline	9.3–10.0	10.1	9.5	14.0–14.5	13.3	13.5	14.1
Isoleucine	—	—	—	1.7–1.8	1.5	1.4	—
Leucine	—	—	—	3.2–3.4	3.4	3.1–3.3	—
Leucine and isoleucine	4.0–4.1	4.1	2.3	—	—	—	5.1
Lysine	2.6–2.9	2.6	2.6	4.5–4.6	4.4	4.1–5.2	4.5
Methionine	0.5–0.6	0.5	0.5	0.8–0.9	0.6	0.8–0.9	0.9
Phenylalanine	1.3–1.4	1.6	1.4	2.2–2 5	2.5	2.1–2.6	2.2
Proline	11.9–12.2	11.9	13.0	14.8–16.4	15.5	16.2–18.0	16.4
Serine	3.0–3.8	3.8	3.6	3.2–4 2	3.7	2.9–4.1	4.2
Threonine	1.8	2.0	1.7	2.2	2.4	2.2	2.2
Tyrosine	0.5	0.3	0.3	0.2–1.0	0.2	0.4–0.9	0.3
Valine	2.0–2.1	2.1	2.2	2.6–3.4	2.8	2.5–2.8	2.6
Amino groups	4.4	4.2	4.1	—	—	—	—

Divakaran (1984), Eastoe (1955), Veis (1964), Gelatin Manufacturers Institute of America (undated).

Table 5.3 — Raw material used to manufacture glue and gelatine

Material	Comments
Trimmings	Frayed edges from sheep, goats and cattle hides available in wet, semi-dried or dried state
Raw	Hair is no problem unless sulphide is present, which will impart colour; dew-claws should be removed because they will also impart colour
Salted	Salt is removed by soaking and washing before processing
Pickled	Salt-cured by a salt-saturated liquid
Limed	Stock limed but not dried
Limed, dried	Stock that is limed and then allowed to dry
Limed and unhaired	Stock limed and hair has been removed
Lime sulphide	Green to greenish black which will impart colour to the extract
Coney	Shredded, dehaired rabbit skin from felt hat manufacturers; it is dried and a very good glue stock
Head	Good raw material, horns should be removed
Lips	Poor quality
Ear tubes	Poor quality
Tail	Poor quality
Scrotal sacs	Should be cut lengthwise before processing
Pizzels	Poor quality
Cow bag	Poor quality
Ear pieces	Low yield, minerals contribute ash and turbidity to glue.
Fleshing	Scraping from flesh-side of skins and hides; available in wet, semi-dry and dried states, variable in collagen content, low yield, produces low quality glue; should be chopped before processing.
Splits	Deeper fleshings made when trimming hide to uniform thickness
Dried and rejected hides and skins	Unless putrefied can be handled like trimmings.
Tanned waste	
Vegetable-tanned	Usually used for leather board; results in low-quality glue
Chrome-tanned, moist	Good yield; glue produced is not of good quality. Low in viscosity and gel strength
Chrome-tanned, dried	Low yield due to difficulty in soaking back
Combination tanned	Difficult to handle

Continued next page

Table 5.3 — *continued*

Pigskins	High content of fat; acid extraction usually used but alkaline extraction will work; can produce good quality gelatin
Poultry skin	Low gel and low viscosity product
Bones	6–40 mm are the most used sizes. Can produce good-quality gelatin.
Green (fresh)	Fresh from killing floor
Packers	Have been cooked to remove tissue and fat, and are dried
Dry	Without odour and low in fat, 25% organic matter
Ossein	Demineralized bone, can produce good-quality gelatine
Sinews	Fibrous coating over bone; separated during crushing, usually contains 5–10% crushed bone, can produce good-quality, high-yield gelatine; also tendons from back of shin bone, may be fresh, salted or dried.
Poultry	Low-gel and low-viscosity product.
Heads	
Knuckles	
Shin bones	
Feet	
Cartilage	
Horn core (piths)	Cartilagenous growth from skull that fills the basal portion of the horn. Can produce good-quality glue by either the acid or alkaline process.
Fish bladder	River and sea catfish, Jew-fish, eels; gelatin obtained is called isinglass
Dried fish bladder	Results in good quality isinglass
Animal casing	Low-quality, low gel and low-viscosity products

between different products but between the same products from different sources and also the same products from the same source may vary from day to day.

There are essentially three processes used to obtain glue and gelatine from collagen stock with variations and combinations of these procedures. The procedures are often described as alkaline-procedure, acid-procedure, and high-pressure steam extraction.

ALKALINE PROCEDURE (TYPE B GELATINE)

The most widely used commercial system for the processing of collagen into glue and gelatine is the alkaline system. Any collagen material (hides, skins, ossein from bones, sinews) can be procesed by this technique. The raw collagen stock is first washed either by a 'cone' mill, which is a cone-shaped chaser revolving in a tank or

Table 5.4 — Yield of glue from various raw materials

Raw stock	Glue (%)	Grease (%)	Tankage (%)	Water (%)
Fresh pork skins	20–25	15	10	50–60
Green salted hide stock	18	3	10	30–40
Dry hide stock	35	1	5–10	10
Green limed hide	14	2–4	8	50–70
Green limed hide split	14	0	5	50–70
Green limed sheep skin	7–9	1–7	5–10	60
Coney stock (dry rabbit skin)	50–55	—	20–25	10
Green limed, fleshings	8–12	5–12	5–10	50–70
Dry fleshings	20–25	5–25	10–20	15
Dry splits	60			
Wet splits	15–25	0	0	40–50
Dry sinews	30–40	0–4	10–30	10–15
Salted sinews	22–24	2–3	7–8	35–50
Dry bones	18–20	1	60–70	10
Wet bone	10–16	5–20	25–45	40–60
Ossein	65–80	0	5	8–12
Dry, horn piths	23–25	0	65–66	8–12

Moulton and Lewis (1953), Tourtellotte (1974), Bogue (1922), Clemen (1927).

vat, or a tumbler of barrel mill (particularly useful for bones) in which a rotating cylindrical drum lifts the stock and drops it through water or a paper-mill pulp washer which consists of a half-round tank and a rotating paddle wheel suspended above, but dipping into, the liquid (similar to the type used in the tanning industry). This washing causes the stock in tanks or pits to be hydrated with cold water. The water is then replaced by a saturated solution of calcium hydroxide made by the introduction of lime (calcium oxide, CaO) into the water. Excess lime is also added to maintain the saturated concentration of calcium hydroxide during the long liming period. An alternative procedure is that the lime water is changed occasionally during the liming period. The quantity of lime used is approximately 10% of the weight of the stock. Any water-soluble bases could be used but lime is normally preferred because its solubility as a saturated solution will regulate the desired alkalinity and because it does not swell collagen as much as other alkaline hydroxides would at the same pH. This alkalinity causes the non-collagen material such as keratin, globulins, muco-polysaccharides, elastin, mucins, albumins and sometimes mucus to be changed to a more soluble product and some of the fats to be converted into polar products so that they can be removed by subsequent washing. The alkaline soak also causes chemical alterations (hydrolytic reactions) in the collagen without appreciable solubilization, so that subsequent thermal solubilization is only required to break weak physical forces that maintain the fibrillar collagen structure. Ammonia (NH_3) is evolved

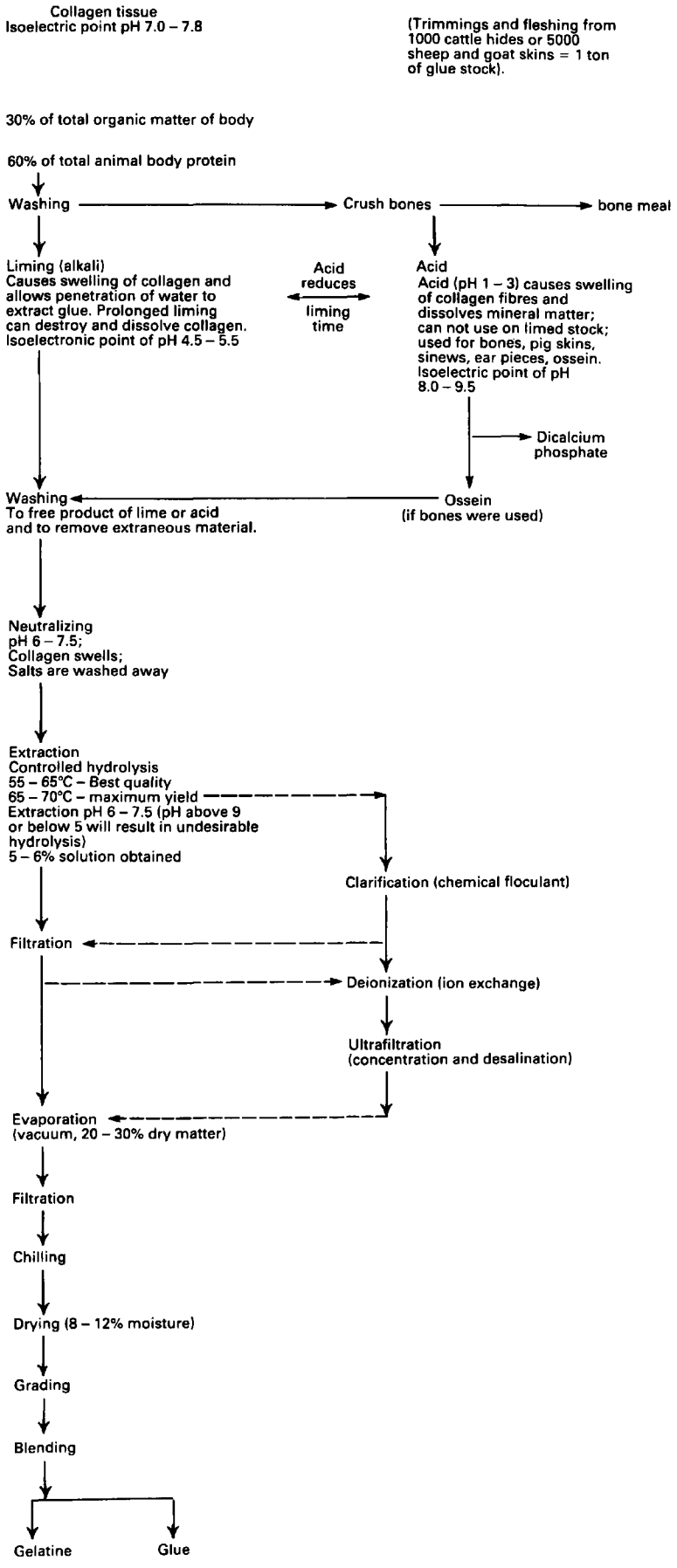


Fig. 5.1 — Flow-chart for glue and gelatine extraction.

during the liming procedure by the hyrolysis of amide groups in the collagen. After the liming of the raw collagen material, the collagen fibres are swollen and the internal cohesion of each fibre is reduced. This is probably caused by rupture of certain peptide bonds and the introduction of new ionic groups into the molecule. This is essentially a depolymerizing reaction in which a few specific peptide-chain regions are cleaved, resulting in hydrolysis in intermolecular cross-link units, which converts a highly polymerized collagen into a product in which only lower intramolecular cross-link units exist, which are readily solubilized in water when the collagen helix is melted by heat. There is also evidence to suggest that the alkali-procedure gelatines are slightly branched chain molecules with an average molecular weight of 30 000 (range 10 000–65 000).

The length of liming depends upon raw material and temperature and the final product that is being produced, but often requires from 7 days to 3 months, ossein requiring a longer liming period. Sinews require 30–45 days of liming; pig skins require 15–20 days and do not require defatting prior to alkaline treatment.

Vegetable-tanned hides are detanned for several days in a mild alkali such as borax ($Na_2B_4O_7$) or sodium carbonate (Na_2CO_3) and then extracted by the alkaline process. Chrome-tanned wastes are alternately soaked in dilute alkali and acid several times or in sodium (or magnesium) carbonates and hydroxides several times until the chromium is leached out. Then the skin is limed, delimed and extracted by the alkali extraction process. It is possible to decrease the liming period by 'sharpening' the alkalinity of the liquor with 0.5% sodium hydroxide (NaOH) or 0.5% sodium carbonate (Na_2CO_3). Sometimes calcium chloride ($CaCl_2$) with 0.1% methylamine (CH_3NH_2) is also added to the lime solution. During this liming period, the isoelectric point of the collagen decreases in pH from approximately 6.0 (day 0) to 4.8 (at 44 days) with the highest-grade gelatine product having an isoelectric pH of 5.0. This decrease in isoelectric pH with time is probably due to splitting off of amide nitrogen, the formation of free carboxyl groups and the release of free basic groups. Also related to the liming period is an increase in the rate of extraction of gelatine, which increases from 6% at day 0 to 37% (extraction per hour, 80°C (176°F)) at 43 days of lime soak. In addition, gel strength (6.66% gelatine) also increases from 86 Bloom (load in grams needed to produce a depression in gel under standard conditions) at day 0 to 182 Bloom at 43 days, and the viscosity also increases with lime soak time. However, overliming — soaking for longer periods of time — could be harmful. Sometimes the collagen tissue degrades and totally breaks down to a stage where gelatine cannot be recovered. Overliming can happen when processing tissue of young animals or when the ambient temperatures are above 30°C (86°F). There are no specific tests that precisely indicate completeness of the liming period. This is still largely guided by experience. After liming is complete, the pH is lowered and the lime is washed (wash milk) from the stock by cold running water (lime is more soluble in cold water) which usually requires 1–2 days. The collagen is still swollen and basic after washing and is neutralized by washing with dilute hydrochloric acid (HCl) or sulphurous acid (sulphur dioxide in water which also bleaches and preserves the stock) until the collagen material is deplumped or limp and flaccid. The acid is then washed out of the product and the final wash is with diluted aluminium sulphate ($Al_2(SO_4)_3$) or zinc sulphate ($ZnSO_4$), which hardens the collagen and slightly improves the colour. If glue is to be made, larger quantities of zinc sulphate are used

to control bacterial growth. The collagen stock should now have a pH between 5 and 8 (normally pH of 6–7) and is ready for extraction.

The delimed collagen stock is then loaded into extraction kettles and extraction takes place in a series (normally six to 12) of liquid 'cooks' ('first run', 'second run', etc.) at successively higher temperatures. Extraction is normally started at 54–60°C, (130–140°F) for 3–5 hours and continues up to boiling. The highest-quality product (higher gel strength and greater clarity) is obtained at the lower extraction temperature, but yield is increased at higher temperatures. It is customary to obtain from 1 to 5% gelatine or glue in each extraction. The residue or 'tankage' left following extraction is pressed, dried and sold as livestock feed or fertilizer. Each extraction is usually kept and dried separately.

The liquid extract is pressure filtered through steam-sterilized paper (cellulose) pulp mats to increase clarity and to remove small particles. Sometimes centrifugation is used but it tends to produce heavy foaming. Gelatine or glue solutions are difficult to filter due to clogging of the filter pores. Diatomaceous earth is often added and this is also removed by filtration (or centrifugation) in an attempt to remove some of the smaller particles after they have combined with the diatomaceous earth. In some research cases (currently not used in industry) a small percentage (5%) of activated carbon is also added at 55–60°C (131–140°F) for 4–6 hours and then removed by filtering (or centrifugation) in an attempt to decolourize the solution by pigments being combined with the carbon and subsequently removed. Another method of clarification is to use aluminium sulphate ($Al_2(SO_4)_3$) or a heat-coagulable protein such as egg albumin (currently not used in industry) and then heat the solution to coagulate the protein. The flocculent precipitant ties up the turbidity-producing proteins which then can be removed by filtration or centrifugation.

Deionization of the gelatine is often necessary if an ash content of less than 0.5% is required. This can be accomplished by passing the solution through a strong cation-exchange resin, intermittently mixed with a strong anion-exchange resin, which is selected to have a rather large particle size of 20–50 mesh. Ultrafiltration with a membrane having a cut off value of 25 000 in molecular weight is also sometimes used as a demineralization process.

Evaporation of excess water is very critical since excess temperature in the presence of moisture (leading to thermal hydrolysis of peptides) will lower the quality and gel strength, and excess time will allow bacterial growth which will also lower gel strength. The first extraction of the collagen material may be of sufficient concentration and gel strength to gel when cooled, but later higher-temperature extractions usually need to be vacuum evaporated in pans before they will gel. This is often accomplished by using a triple-effect evaporator or by heating the solution in a plate heat-exchanger to 80–90°C (176–194°F) and then concentrating it in a vacuum evaporator. Vacuum evaporators usually convert gelatine to 20–25% concentration, glue to concentrations of 11–17% for hide-glue liquor, 33–42% for bone-glue liquors and as high as 50% for low-test or quality glues.

The concentration gelatine or glue solution is next placed on a belt and chilled and the solid jelly (maximum 12 mm ($\frac{1}{2}$ in) thick) is stripped from the belt and placed upon nets (wire screens) which are held by frames. The frames holding the gels are then placed in drying tunnels. Air entering these tunnels is washed, filtered, and dried prior to being introduced (enters counter-currently: in the opposite direction to

glue travel so that the driest air contacts the driest glue) and the temperature is gradually raised (to prevent skinning or case-hardening). If the air is dry, evaporation from the jelly is sufficient to cool the jelly and keep the temperature below the jelly's melting point. In 8–12 hours a 10% (8–12% range) moisture, brittle, transparent, thin sheet is produced. Other methods of cooling include a slowly rotating, brine-cooled drum or a tumbled heat-exchanger where the gel is formed and forced through a noodling or dicing head. The product is then sold in sheets or broken and milled to 35–40 mesh and in some cases is powdered.

Drum drying with equipment similar that used to produce dry milk powder is an alternative method of removing moisture. Clarified liquor is placed in a thin sheet on a large (6.1 m (20 ft) in diameter) steam-heated drum and in less than 1 minute a film of dry gelatine or glue is removed by knives.

'Pearl' or 'bead' dried glue is made by dropping liquid glue from a tower into cold white spirit (a high-boiling paraffin) or naphtha. The pellets (small beads) formed are more easily dried and are of greater durability than sheet glue. Spray drying has also been investigated and consists of forcing small droplets to fall into a high spray-drying chamber (again similar to equipment used in producing dry milk powder).

After drying, the gelatine or glue may be sold in sheets or coarsely broken, often to a 35–40 mesh in a hammer mill to give flake gelatine, or pulverized and powdered to form granulated gelatine. The gelatine may also be extruded as noodles or in thin ribbons onto a moving belt and dried.

Usually the desired viscosity and gel strength of the dried product is obtained by blending products of the same mesh size from different extractions.

Preservatives such as zinc sulphate ($ZnSO_4$; irritating to mucous membranes) or sulphur dioxide (SO_2, irritating) are used in the glue industry. Preservative effectiveness depends upon gelatine concentration (gels are more difficult to preserve than dilute solutions) and other additives. The preservatives shown in Table 5.5 have been reported in the literature (Divakaran, 1984; Gelatin Manufacturers Institute of America, undated).

Other substances such as glycerol ($C_3H_8O_3$) or sugar ($C_6H_{12}O_6$) or tar oil have been added to improve glue flexibility. Calcium chloride ($CaCl_2$), sodium naphthalene sulphonate ($NaC_{10}H_7O_4S$), acids and chloral hydrate ($CCl_3CHO.H_2O$) may be used to produce a liquid glue.

ACID PRECURSOR (TYPE A GELATINE)

Acid processing of collagen stock is usually applied to pig skins and bone even though it is possible to prepare gelatine from any collagen stock by this method. This technique is particularly desirable if the raw material contains any bone or cartilage. Acid processing is particularly important in the U.S. when preparing edible gelatine from frozen (most popular) or salted pigskins (up to 1.3 kg (2.8 lb) of skin/hog). Pig skins are first washed to remove salt from salted skins and to remove extraneous matter and/or blood from frozen skins that have been defrosted. Since pigskin frequently contains 8–15% fat, pre-extraction of this lipid material is desirable before the acid extraction procedure. This is normally done by heating the skins in hot (55–60°C (131–140°F)) water, two to three times, stirring them for 4–6 hours and skimming the melted fat from the top. The skins are then washed in 40–55°C

Table 5.5 — Preservatives

Preservative	Formula	Percentage required	Notes
Acid Conditions (pH 3–4)			
Alcohol	C_2H_6O	8.0	
Chlorobutanol	$C_4H_7Cl_3O$	0.5	Minimum lethal dose (MLD) in dogs, 238 mg/kg
p-Chloro-*m*-cresol	C_7H_7ClO	0.25	Very toxic
Ethylparaben (ethyl *p*-hydroxybenzoate)	$C_9H_{10}O_3$	0.15	
Sodium penta-chlorophenate	Na salt of C_6HCl_5O	0.1–0.15	Very toxic
Methyl paraben (methyl *p*-hydroxybenzoate)	$C_8H_8O_3$	0.1–0.15	Allergen for some people
Benzoic acid	$C_7H_6O_2$	0.1	Mild irritant
Oxyquinoline	C_9H_7NO	0.1	
p-Chloro-*m*-xylenol	C_8H_9ClO	0.1	
Propyl paraben (propyl *p*-hydroxybenzoate)	$C_{10}H_{12}O_3$	0.1	
Salicylic acid	$C_7H_6O_3$	0.1	Forbidden in some countries
Thymol	$C_{10}H_{14}O$	0.1	Medium lethal dose (LD_{50}), lethal for 50% of subjects, for mice, 1.8 g/kg
Butylparaben (Butyl *p*-hydroxybenzoate)	$C_{11}H_{14}O_3$	0.05	
Cetylpyridininium chloride	$C_{21}H_{40}ClNO$	0.003–0.005	LD_{50} for rats, 200 mg/kg
Basic conditions (pH 7–8.5)			
Alcohol	C_2H_6O		
Chlorobutanol	$C_4H_7Cl_3O$	0.5	MLD in dogs, 238 mg/kg
Phenol	C_6H_5OH	0.5	Toxic
Cresol	$HOC_6H_4CH_3$	0.4	8 g causes circulatory collapse
p-Chloro-*m*-cresol	C_7H_7ClO	0.25	See above and cresol
Ethylparaben (ethyl *p*-hydroxybenzoate)	$C_9H_{10}O_3$	0.15	
β-Naphthol	$C_{10}H_8O$	0.2	LD in rabbits, 3.8 g/kg
Chlorothymol	$C_6H_{13}ClO$	0.1	
p-Chloro-*m*-xylenol	C_8H_9ClO	0.1	
Thymol	$C_{10}H_{14}O$	0.1	Side-effects with elevated dosage
Cetylpyridinium chloride	$C_{21}H_{40}ClNO$	0.005	LD_{50} in rats, 200 mg/kg

(104–131°F) water. Solvent extraction of fats from pigskins is also possible and usually food-grade hexane [$CH_3(CH_2)_4CH_3$] or ethylene dichloride ($C_2H_4Cl_2$) is used, followed by a washing to remove the solvent residues. However, these are not frequently used commercially because the emulsions formed are hard to work with.

Well-fleshed (if excess fat is present on the skin it will cloud the finished product) pigskins are thawed if frozen, washed in cold water and soaked in up to 5% (1 N for sinews) inorganic acid such as hydrochloric (HCl), sulphurous (sulphur dioxide (SO_4) in water), phosphoric (H_3PO_4) or sulphuric (H_2SO_4) which results in a pH of approximately 4. Sulphuric acid or sulphurous acid are often used at 1–1.5 N but longer soaking times are usually required. This pH causes the collagen to swell and a great deal of solubilization to take place. The acid soak usually lasts from 10 to 72 hours (24–48 hours for sinews, 48–72 hours for swim bladders) and is often replaced with fresh acid at 24 to 36 hours. Continual acid soaking may increase yield but may also lower gel strength and viscosity. The acid is then drained and the collagen is washed to raise the pH of the skin to approximately 4–5. Sometimes the collagen is given a 5–8% sodium hydroxide rinse to raise the pH to 6–6.5. Continued washing removes the salts that were formed. If sulphuric or sulphurous acids are used, the salt is less soluble and more care must be taken in washing. Most of the non-collagenous proteins have an isoelectric point of pH 4–5 and consequently are least soluble and rapidly coagulated during extraction. At this pH the native collagen is still swollen. Acid preparation yields a gelatine with an isoelectric point of 8.9 (range 8.5–9.4). Acid processing seems to cause only physical reorganization of the collagen structures with minimal hydrolytic changes, which result in a small increase in primary amino groups and free carboxyl groups. Average molecular weights for acid-precursor products are in the range 70 000–90 000, except for sturgeon swim-bladder gelatine which has a reported moleculer weight of 250 000.

After acid treatment the collagen stock is extracted using the previously described alkaline-precursor treatment, except that pigskins can be extracted at a lower starting temperature than cow hides. Filtration is also easier with the pigskin acid-extracted products. Drying is accomplished in a similar manner as used for the alkaline-procedure products.

The gelatine produced from pigskins has a higher gel strength and better clarity and colour than alkaline-treated cattle-hide products. Sinews result in a good quality product and multiple extractions are usually used. Settling and clarification of sinews extracts are usually accomplished at 50–60°C (122–140°F) and a fairly clear extract is obtained. If sulphuric acid or sulphurous acid is used, more turbidity is encountered and filtration or flocculation may be necessary. Sinew-extract drying may be by the drum method or higher-grade final products may be dried by the chilling and tunnel-drying method.

Isinglass is extracted in 55–60°C (131–140°F) water for 4–6 hours. Old stock may require a second extract. The extract is filtered, concentrated by continuous-flow centrifugation and vacuum evaporation. It is then drum-dried or chilled (5–10°C (41–50°F)) and oven- or tunnel-dried (60–70°C (140–158°F)) to an 8–10% moisture level.

In summary, it would seem that acid-precursor gelatine has maintained many of the covalent cross-linkages of collagen, and some have even suggested that acid-precursor gelatine should be called melted soluble collagen. Acid pretreatment yields a gelatine with an isoelectric point of 8.9 and acid processing seems to cause only physical reorganization of the collagen structure with minimal hydrolytic changes, which result in a small increase in primary amino groups and few carboxyl groups.

The acid-conditioned material is now subjected to a series of 'cooks'. The initial extraction is at approximately 60°C (140°F) (range of 55–65°C (131–149°F)) and the temperature is raised by 5–10°C (9–18°F) on each successive extraction. Eight to ten extractions are commercially made and the product is quickly dried to prevent degradation and microbiological contamination. Each dried extraction is graded for gel strength and viscosity and the product is blended for desired properties.

It should be recognized that alkalkine and the acid-precursor-produced gelatine are two different classes of gelatine and that they are different products and cannot be used interchangeably by the user.

OSSEIN PRODUCTION FROM BONES

Bones are often pretreated (see Fig. 5.2) by washing in water and in dilute sulphurous acid, and are sometimes degreased with benzene. They are frequently lightly cooked with 80–95°C (176–203°F) water or heated to this same temperature by steam to remove adhering meat, gristle and fat (melts and separates). Undercooking gives greasy bones and overcooking results in brittle chalky bones; both are considered undesirable. Next day they are washed (rotary washer or high-pressure spray) and the 'washings' are saved and rendered into tallow and fertilizer material. The clean bones are then slowly dried (too rapid drying causes bones to split) on steam coils or by steam-coil-heated air. The adequately dried bones (insufficient drying causes bones to decompose) are stable at this state and will keep indefinitely and can be marketed as 'packer bones'.

Normally the next step is milling (a stone crusher can be used) and screening of the bones (1–6 cm^3 (0.4–2.4 in^3)). The larger fragments (see Table 5.6) are separated into hard bone, soft bone, and sinew fractions. The soft bone and sinew allow more rapid penetration of acid and are more susceptible to physical breakdown during liming than hard bones. For these reasons, the two types are handled separately during further processing. Next the bones are extracted with a non-polar solvent (i.e. ethylene dichloride ($C_2H_4Cl_2$, fairly non-flammable), hexane ($CH_3(CH_2)_4CH_3$, a food grade is used for edible gelatine), or gasoline) to remove any remaining fat if the bones contain over 0.5% fat. The bones are then dried in ovens (50–60°C, (122–140°F)) to remove the solvent. The bones then may be pressure-steam extracted as described in another section, but this usually produces a lower-quality gelatine.

Ossein is normally produced from bones by acid removal of minerals prior to steam extraction. This involves treating the bones (counter-current demineralization) with hydrochloric acid (HCl) to remove the mineral matter:

$Ca_3(PO_4)_2$+	4 HCl	⟶	$Ca(HPO_4)_2$+	$2CaCl_2$
Calcium phosphate	Hydrochloric acid		Soluble monocalcium phosphate	Calcium chloride

The counter-current demineralization is used to obtain maximum efficiency of the acid and requires six to eight acid-resistant vats of a size 1.5–2 times the volume of

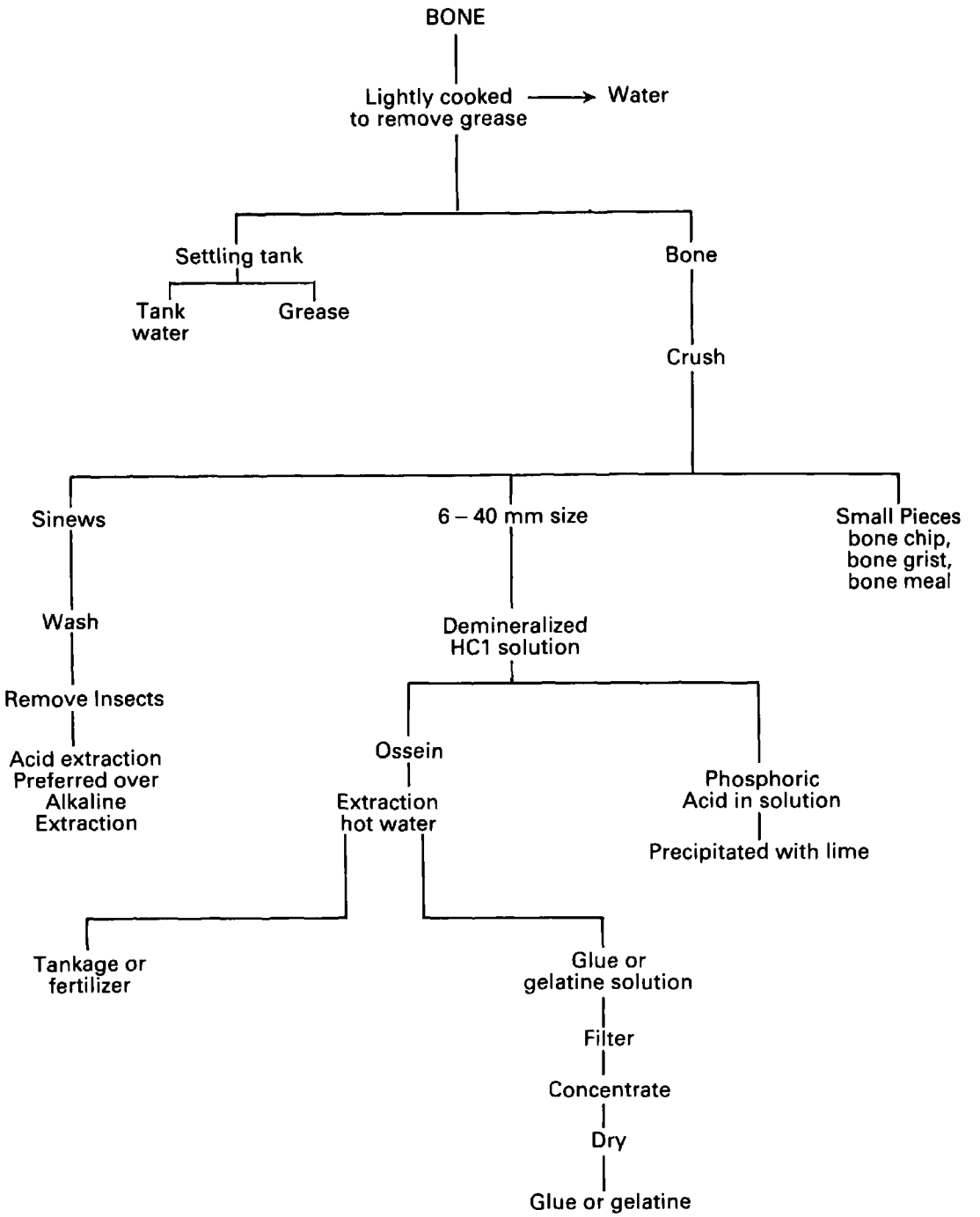


Fig. 5.2 — Glue and gelatine extraction from bone.

the bones. Crushed (1–3 cm^2 (0.4–1.2 in^2)) bones are placed in the vats and a 1 N (commercial acid diluted 10:1) chilled (4–10°C (39–50°F)) hydrochloric acid (HCl) solution is pumped into the first tank and a liquid circulating pump is used to keep the acid and bone mixture stirred. The extracting mixture should be maintained at not more than 25°C (77°F) and extraction should continue for 24 hours. The used acid is pumped to the second vat and fresh chilled acid is added to the first tank. This cycle of sending used acid to another vat is continued until the acid has passed through all the

Table 5.6 — Yield of crushed bone

Categories	Percentage
Crushed bone (18, 12, and 8 mm size)	55–60
Bone grist (6 mm)	10
Bone meal (fines)	10
Sinews	10
Tallow	3–5

Divakaran (1984).

vats and the first vat has been extracted with six to eight cycles of fresh acid. The ossein in the first vat is now washed in water until the waste water has a pH of 6–6.5. The ossein is removed from the first vat, which is recharged with fresh bones, and now the second vat receives the fresh acid which continues the cycle and passes last through the first vat. The process is now cyclic in nature. Ossein produced by this technique should have less than 2% ash on a moisture-free basis. If it is higher than this it suggests incomplete demineralization. The strength of used acid should be checked periodically by precipitating (by addition of approximately 30 g of calcium hydroxide ($Ca(OH)_2$)/l of spent acid to raise the pH to 5.5 or 6) the dicalcium phosphate ($Ca_2P_2O_7$) and weighing it to determine if the acid is saturated and will not dissolve any more minerals from the bone. In general practice it usually requires an equal weight of acid to demineralize an equal weight of bone.

An alternative to the counter-current procedure is to have the acid constantly pass through the various vats at 25°C (77°F) (requires cooling) until the acid is saturated. Other processors use a 4–5% concentration of hydrochloric acid at 15°C (59°F) and treat sinews for one to two days and hard bones from four to six days. The final ash content of the ossein is from 1–2% in both cases.

Washed ossein contains 60–85% moisture and, if not converted into gelatine quickly (highest yields), has to be dried very carefully to prevent uncontrolled hydrolysis to gelatine. It is usually placed on drain trays, and gravity drainage is accomplished first. It is then placed in a perforated drum of a batch or continuous hydroextractor (centrifuge type) in which centrifugal force reduces the moisture level to 15–20%. The ossein is then rapidly dried in hot convection air-drying ovens (50–60°C (122–140°F)) to 8–10% moisture level and then rapidly air-cooled. It can then be stored in moisture-proof bags almost indefinitely, but continuous hydrolysis during storage would suggest processing into gelatine within 6 months. The dried ossein is an excellent raw collagen material for alkaline (3–6 weeks of liming) or acid (more popular) treatment before gelatine or glue extraction. Dry ossein is soaked for 12–14 hours prior to liming. The rehydrated ossein is placed in liming pits and lime is added at the rate of 10% of the dry weight of the ossein. Liming requires 30–60 days (longer for older ossein stock, and longer in colder climate), the lime liquor should be agitated with a slurry pump and fresh lime liquor added once or twice during the liming period. The ossein is then processed through deliming, washing and gelatine extraction; the drying of gelatine is similar to the previously described processes for gelatine and glue.

If ossein is acid- extracted for the production of gelatine, the wet ossein from the final acid vat is washed until the pH is 6.5–7 and the ossein is extracted without drying, or, if already dried, may be soaked in acid and then processed as just described. Again the extraction and drying of gelatine has been previously described. If the alkaline process is used, the lime may be washed and the ossein treated with an acid to produce an acid-extracted-like product similar to pork-skin gelatine.

The spent acid from bone demineralization contains tricalcium phosphate ($Ca_3(PO_4)_2$, hydroxyapatite) in solution. Calcium hydroxide ($Ca(OH)_2$) is added (approximately 30 g/l) to this solution until the pH is raised to 4.2–5.5. After continuous stirring for 4–6 hours the liquid is allowed to settle for 36–48 hours and the clear supernatant waste effluent is pumped out and the solid dicalcium phosphate ($Ca_2P_2O_7$) is pressed and then heated (60–65°C (140–149°F)) in an air oven (or tunnel) and dried to a 5% moisture level. The white, free-flowing dried dicalcium phosphate is used in the fertilizer industry as a phosphate supplement, in animal feed as a mineral supplement, or as a filler in the paint and pigment industries.

Bones are crushed into sizes as shown in Table 5.7.

Table 5.7 — Use of different crushed bone sizes

Bone size (mm)	Bone size (in)	Bone use
18	$\frac{3}{4}$	Glue, gelatine
12	$\frac{1}{2}$	Glue, gelatine
8	$\frac{3}{8}$	Glue, gelatine
6	Bone grist	Poultry feed
Fines	Bone meal	Feed, fertilizer

The crushed bones have previously had the fat removed (collected from a washing process) by hot water and, if necessary, they are rewashed to prepare for extraction of gelatine and glue with steam at 1–3 kg/cm^2 (15–45 psi) and again extracted with hot water. This system has the advantage of being rapid and requires no pretreatment, but produces a glue with variable viscosity and gel strength. Hydrolysis is accomplished by thermal shock at high temperatures for a short time followed by a quick cold-water chill. The collagen is not denatured by the heat because it is surrounded by a sheath of hydroxyapatite crystals (lattice of mineral tricalcium phosphate). This process is repeated several times to obtain several extracts. The gelatine is later extracted at lower temperatures (initially at 60–70°C (140–158°F)) to prevent degradation. This extraction is repeated at higher temperatures until less than 1–2% glue is obtained. Repeated extract cycles produce reduced gel strength and viscosity. Under ideal conditions 25% by weight of glue can be extracted. Further processing is similar to that previously described. The insoluble mineral salt (primarily calcium phosphate) is soft and chalky and is sold as steamed or dry bone meal (or flour) and is used in the animal feed (not used for feeding if there is a possibility of anthrax) and fertilizer industry (steamed bone flour, 18% moisture).

Green bones may be boiled (poor yield) with only a washing and a change or two of weak acid. If this system is used, the boiling time is increased to approximately 24 hours, higher extraction temperatures are used and 5 or 6 'cooks' are used. This system is not as popular as the pressure system.

EXTRACTION OF OTHER MATERIAL FOR GLUE

In addition to isinglass (previously described), the fish industry also produces glue from fish by-products and the raw material and properties may be found in Table 5.8.

Table 5.8 — Glue made from fish products

Raw material	Properties
Fish-skin glue	Good quality
Fish waste (triming and bones) glue	Low quality
Fish-head glue	Normally turbid, often combined with zinc oxide for wood glue

Divakaran (1984).

Blood albumin glue is a waterproof glue that may be extracted from fresh blood or dried albumen.

USES OF GELATINE OR GLUE

Levels of gelatine incorporated into food are usually fairly small. Gelatine is normally used to modify the physical properties of food; for example, an ordinary gelatine dessert is 1.5–2.5% gelatine. Gelatine for desserts (type A or B or a blend, with a Bloom rating of 175–275 (see the explanation of Bloom rating in the next section, 'Physical properties')) is available in packaged form flavoured with sugar ($C_{12}H_{22}O_{11}$) or low-calorie sweetners; contains an acid such as citric ($C_6H_8O_7$), tartaric ($C_4H_6O_6$), adipic ($C_6H_{10}O_4$) or fumaric ($C_4H_4O_4$); contains a fruit or aromatic flavouring, and in some cases a buffer such as citrates, tartrates or phosphates; and in some cases contains salt (NaCl). It is available in some countries a a firm, rubbery jelly tablet (5×7.6 cm (2×3 in) rectangular), usually available in a plain unflavoured form, and recently has become available at the retail level as fully-prepared gelatine desserts or salads. The powdered or tablet form only requires dissolving in hot water and chilling.

In marshmallows, 1–2% gelatine (250 g (Bloom)) transforms a 20% sugar syrup (lowers its surface tension) into a highly viscous solution, which can be whipped (the gelatine stabilizes the foam through increased viscosity) with large amounts of air, cast in starch or cut to form a solid product which will melt in the mouth.

A low Bloom gelatine is used to make 'drops' and 'particles'. The higher the gelatine concentration the slower the confection dissolves and the longer the flavour

is maintained. Gum drops in Europe are also made with gelatine. Lozenges and wafers contain some gelatine (50–100 g (Bloom)) to hold them into shape while they are extruded, cut and dried. A 1% medium-strength gelatine is used in hand-dipping of 'bonbon' coatings and gelatine is also used in connection with chocolate-coating, using equipment instead of hand-dipping.

In ice cream the protective colloidal action of 0.3–0.5% (250 Bloom) gelatine is used to modify whipping qualities, body, texture (it reduces coarseness) and keeping qualities and the retardation of ice and sugar (lactose, $C_{12}H_{22}O_{11}$) crystal formation during storage. Other dairy items such as cottage cheese and sour cream use small quantities of gelatine to prevent watering and to maintain a smooth texture. Gelatine incorporated into milk lowers its curd tension and makes it more digestible. In frozen foods such as cream pies, sauces and gravies, gelatine is used to reduce the formation of large ice crystals and to prevent curdling and separation.

In the meat area (1–5% gelatine is often used) many specialty items, such as jellied tongue, jellied beef, corned beef, loaves, scrapple, brown sauces, aspics, consommés, meat pies, and glaze for loaves and hams, employ gelatine (it fills voids between the casing and the loaf, resulting in a smooth appearance). It is also used to fill the voids and absorb liquids in canned meat (0.4–1.5%) and poultry products (i.e. turkey and chicken rolls). The gelatine binds the water and meat juices and results in a stable firm product. Dry gelatine may be sprinkled in bone cavities of boneless hams to bind the meat together.

Gelatine is used as a food-thickening agent, emulsifying agent and in small quantities for clarifying (i.e. isinglass) beer, wine, fruit juice and vinegar, and for pharmaceutical products. When used for clarification of drinks, if done properly it does not modify the organoleptic properties of the product. The gelatine reacts with tannins, pectins and similar material in the presence of a catalyst (e.g. iron), flocculation occurs and clarification is completed by filtration or centrifigation. Both type A and type B gelatine, as well as isinglass, have been used in the 0.002–0.015% range.

Gelatine is also used to manufacture pharmaceutical capsules (see Table 5.9). The 'hard' capsules or the two-piece ensembles into which the pharmacist adds powders are made entirely of gelatine with no other additives except, in some cases, colouring. The 'soft' or 'elastic' capsules contain a plasticizer, usually glycerol or propylene glycol, and are often used to contain cod liver oil and other vitamin products. A method for enclosing dry material has been developed and antibiotics can be handled in this manner. Gelatine is also used to coat pills to help eliminate crumbling, sticking, evaporation of moisture and taste when swallowing.

Gelatine (10–20%) is used as a moisturing agent in making tablets, so that they are pleasant and smooth to the tongue, and a binder and a disintegrator (it absorbs moisture causing the tablet to swell and break up). Glycerinated gelatine is used as a base to manufacture pastilles, lozenges and 'cough drops', which are used to apply medicaments to the mouth and throat. Gelatine is also used as a carrier or binder for various drugs, not only for its binding ability but because is often protects the drug from atmospheric oxidation. Gelatine is also an excellent stabilizer for all emulsions used in the pharmacy area. Gelatine is used in emulsions so that a single shake will restore the emulsion to its original condition. Gelatine (type A, 18%) has also been

Table 5.9 — Properties of gelatine

Property	General specifications	
	Type A cationic acid technique	Type B anionic liming technique
Iso-electric point (IEP)	7.0–9.5	4.7–5.5
pH	3.8–6.0	5.0–7.5
gel strength/(gm) (Bloom)	75–300	75–275
Viscosity (mp)[a]	20–75	20–75 (in general lower than the acid product)
Ash (%)	0.3–2.0	0.05–2.0
		U.S.P. Pharmagels
	Pork skins	Bones, hides
Raw material		
Isoelectric range	7.8–8.2	4.7–4.9
pH (25°C, 1.5% solution)	4.0–4.3	5.5–7.3
Gel strength (g) (Bloom)	250	225
Viscosity (mp)[a]	38–45	40–70
Ash (%)	Less than 0.4	1.0–1.5
Particle size	36 mesh	36 mesh
Total bacterial count	Less than 5000/g, No coliform in 0.1 g	Less than 5000/g, No coliform in 0.1 g
Metal	U.S.P. requirements	U.S.P. requirements
Soft capsules		
pH	5.0–5.5	5.5–7.3
Gel strength (g) (Bloom)	170–180	150–175
Viscosity (mp)[a]	30–35	35–40
Ash (%)	Max 0.5	Max 2.0
Total bacterial count	Max 1000/g	Max 1000/g
Coliform	No coliform in 0.01 g	No coliform in 0.01 g
Salmonella	Negative	Negative
Hard capsules		
pH	4.5–5.5	5.3–7.3
Gel strength (g) (Bloom)	250–280	220–250
Viscosity (m)[a]	45–50	45–60
Total bacterial count	max 1000/g	Max 1000/g
Coliform	No coliform in 0.01 g	No coliform in 0.01 g
Salmonella	Negative	Negative

[a] Consult reference Gelatin Manufacturers Institute of America, 1964, for details of test.
Tourtellotte (1974), Divakaran (1984), Gelatin Manufacturers Institute of America, (undated 1982).

employed in delaying the absorption of a number of drugs (e.g. heparin, adrenocorticotrophic hormone (ACTH), epinephrine).

Manufacture of enteric coated capsules and tablets has been attempted by treating the capsule with formaldehyde (HCHO) or coating the capsule with phenylsalicylate ($C_{13}H_{10}O_3$) or butyl stearate ($C_{22}H_{44}O_2$) or carnauba wax, or stearic acid ($C_{18}H_{36}O_2$), or cellulose acetate phthalate. Suppositories often also use glycerine gelatine as a base for controlled release of ingredients. A 7% isotonic

solution is often used for cardiovascular patients. A gelatine marshmallow containing barium sulphate ($BaSO_4$) is sometimes used for fluoroscopic examination because it slows the passage of barium sulphate through the digestive system. Gelatine is also used as a medium for external application of drugs, (i.e. zinc oxide (ZnO), antiseptics, sulphonamides, and penicillin) to treat various skin disorders. Gelatine paste (glycerinated gelatine and zinc oxide) may be used as an adhesive substitute to hold bandages or dressings in areas hypersensitive to tape.

Absorbable gelatine sponges or gelatine foam powder are also used in surgery as a means of arresting oozing haemorrhages. As the wound heals, tissue enzymes dissolve the gelatine. Gelatine is also used for dusting surgical gloves since traces left in the body will be dissolved.

Gelatine has been developed as a plasma expander for the treatment of haemorrhages, trauma and burns. Products are described as 5 or 6% solutions, with a molecular weight of 20000 or 36000, in normal saline. These expanders restore blood volume and blood pressure and will last in most patients for 24 hours.

Gelatine is used in the cosmetic area and in wave-set lotions. Some of its properties used in cosmetics are its adhesive and emulsifying powers.

Gelatine is also important in photography and is used to make baryta-coated paper. Films are coated with gelatine, which contains the light-sensitive silver reagent. The gelatine controls the size of the silver halide grain and protects it from the reducing action of the developer so that the reduction is proportional to the exposure to light.

It is also used in making smokeless gunpowder.

Gelatine is used in insecticide sprays for its sticking power and in feed formulations that contain a large percentage of leaves. Gelatine also finds uses in microencapsulation (e.g. a duplicate copy with 'no carbon paper'), as a foamer in ore floatation for separation of minerals and as a foamer in fire extinguishers.

Glue is used to join wood to make plywood, but some of the largest uses today are in the manufacture of gummed tape, boxes and tubes. Glue or technical gelatine is also used for applying colours to wall paper, as a size to strengthen paper and to fill in pores to improve printing quality (glue with alum gives paper a harder finish), as a coating for non-silver photocopying paper, to give a permanent wave to crepe paper, as a size for fabric to strengthen rayon and acetate yarns and reduce breakage (washed out after use), as a size for heavy fabrics to give stiffness, to waterproof fabrics, as a size for window shades, as a size for barrels and casks to prevent the liquid from penetrating the wood, as a size for walls to fill pores before painting, to bind and protect the chemicals in the manufacture of matches, in the making of plastics (i.e. polyvinyl chloride $(CH_2{=}CHCl)_n$), as a binder for abrasive wheels, mixed with calcium carbonate ($CaCO_3$) and sawdust to make ornate mouldings, to make composition cork used in gaskets and bottle caps, in the manufacture of sandpaper, in electrometallurgic processes to give a smooth surface, as a zinc brightener, to make printers' rollers, to make wiper rollers for multicolour printing and offset lithography, in rubber to add oil resistance, and in the making of India ink. Gelatine acts as an adhesive for stamps and labels, in making packaging ribbon (binds threads that run only in one direction), laminating glass and production of decalcomanias. Gelatine is also used to make films and filters for spotlights and cameras.

In the laboratory, gelatine is used as a microbiological culture media and to determine the strength of enzymes.

PHYSICAL PROPERTIES

Gelatine is nearly tasteless and odourless and is a vitreous brittle solid with a relative density of 1.3–1.4 kg/l. When immersed in cold water gelatine hydrates into discrete swollen particles, and when warmed these melt to a dispersion. Gelatine is also soluble in polyhydric alcohols (e.g. glycerol ($C_3H_8O_3$) or propylene glycol ($C_3H_8O_2$)) but is not soluble in organic solvents (e.g. benzene (C_6H_6), ether ($C_4H_{10}O$), acetone (C_3H_6 O), on carbon tetrachloride (CCl_4)). Gelatine is composed of 50.5% carbon, 6.8% hydrogen, 17% nitrogen and 25.2% oxygen.

Depending on the pH of a water solution of gelatine, it can act as either an acid or base, making it amphoteric. It can also undergo reactions such as acylation, esterification, deaminization, cross-linking and polymerization.

Not all gelatines are the same and they are subdivided into an acid-treated precursor (type A) which has an isoelectric point between pH 7 and 9.5 and an alkali-treated precursor (type B) which has an isoelectric point between 4.7 and 5.5 (See Table 5.9); therefore not all gelatines function in a similar manner. It is possible to modify the manufacturing procedure and produce gelatine with an isoelectric point between type A and type B. Gelatine samples also differ in molecular size and this influences their physical properties.

Gelatine colour in a dilute solution should be colourless to light amber or faintly yellow; lower grades will have an orange–brown colour. Clarity is checked by looking at print through a beaker of solution or observing a solution in a strong light. High-quality gelatine should be clear and sparkling and have only a trace sediment of foreign material; lower qualities will be opalescent to cloudy. The colour of gelatine depends on the raw material extracted (pork-skin gelatine is lighter than bone or hide) and whether it is the first, second or later extractions. In general, colour does not influence other properties of usefulness. Turbidity is usually associated with poorly processed or low-grade gelatines. Turbidity is caused by insoluble or foreign material that is in the form of an emulsion or a dispersion or an isoelectric haze (maximum at 2%). If colour is important to the product, then bleaching of the raw material or the use of de-colouring agents (e.g. activated charcoal) may be necessary.

The viscosity of gelatine is evaluated by the time required for a standard concentration (usually 6.67% or, in some procedures, a 1% solution; viscosity increases with concentration of gelatine) of solution to flow from a standard viscosity pipette (often 100 ml), to flow through a 'U' tube viscometer, or to exit by a standard orifice from a cup, or by use of the resistance offered by a dynamometer spindle immersed in a fluid. Viscosity measures are influenced by temperature (60°C (140°F) often used) and this would be standardized (see Table 5.9). Molecular weight seems to be more important in viscosity measurements than it is in gel-strength measurements.

Gel strength is a measure of the hardness, stiffness, strength, firmness, and compressibility of a gel at a particular temperature. It is also influenced by

concentration and molecular weight. The gel formation is believed to be caused by hydrogen bonding, with the molecules of gelatine arranged in micelles, forming a semi-solid gel and binding water. Gel strength is tested on a Bloom gelometer which measures the resistance to depression of the jelly surface by a plunger under standard conditions. The conditions for the Bloom gelometer consist of a $6\frac{2}{3}$% solution chilled to 10±1°C (50°F) for 17 hours in a container of standard dimensions. A 12.7 mm ($\frac{1}{2}$ in) diameter circular plunger is loaded with shot until it depresses the jelly surface 4 mm (0.16 in). The weight in grams of the shot is the Bloom test or Bloom rating or jelly strength. Commercial gelatines range from 50 to 300 g (Bloom). Since gelatine is an amphoteric compound, it can have either a positive or a negative charge depending upon its pH and its isoelectric point. Type A gelatine is cationic below pH 7 and type B is cationic below pH 4.7. Gelatine is a hydrophilic colloid. It has a protective colloid action and will stabilize many hydrophobic colloids (has a very low Zsigmondy gold number).

The measure of refractive index provides information on concentration, which is usually correlated with gel strength and viscosity.

Standard microbial techniques are used to evaluate the bacterial, mould and yeast quality of gelatine. Most food gelatines contain less than 3000 bacteria per gram and these are not pathogenic. The U.S.P. maximums are 1000/g and *Salmonella* and *Escherichia coli* must be absent. If the gelatine has a pH value below 4 then bacteria growth will be suppressed, but moulds and yeast will continue to grow; if the pH value is above 5 then proteolytic bacteria can be expected.

Chemical tests for gelatine include moisture analysis. Moisture is normally between 9 and 13% (range 7–15%) and will vary, not only with the extent of drying, but also with the humidity of storage and the moisture permeability of the package container. Ash content for gelatine has a maximum (U.S.P.) level of 2%; however, high-quality gelatine should have no more than 0.5% ash. Ash level varies with the type of raw materials extracted (pork skins contain small amounts of chloride and sulphates, ossein contains calcium phosphate, hide contains calcium sulphate) and the method of processing. If a very low ash level is needed, the gelatine may be passed through an ion-exchange procedure for demineralizing or de-ashing. Sulphite is sometimes added to gelatine to be used for capsule manufacturing (0.15% SO_2) or for some photographic uses. The U.S.P. maximum level for other gelatines is 0.004%. The mineral level of gelatine for arsenic is a maximum (U.S.P.) of 0.8 ppm, but high-quality gelatine has none. The U.S.P limit for heavy metals is 50 ppm. Copper has a maximum of 30 ppm and high quality gelatine has less than 5 ppm. Zinc has a maximum level of 100 ppm, but high-quality gelatine has less than 15 ppm. Lead has a maximum level of 2.57 ppm and high-quality gelatine has none.

WASTE FROM GELATINE AND GLUE PRODUCTION

A sludge paste containing mud, hair, vegetable matter and protein remains after glue and gelatine extraction and filtration or sedimentation, and this residue contains a base layer and a upper fat layer. The insoluble portion is pressed to expel grease and glue or gelatine liquor, and the pressed product is dried and used as tankage. Where alkaline processing is used, the effluents contain mostly lime along with hide protein,

dirt, and hair. The properties of effluent and solid waste can be found in Tables 5.10 and 5.11.

Table 5.10 — Effluents from glue and gelatine

Extraction method	Raw material	Waste (l)	BOD (kg)	Suspended solids (kg)
Per tonne of bone				
Acid	Bone to ossein	10000	Less than 2%	2%
Per kilogram of glue or gelatine				
Alkaline	Trimming fleshing	200	1	2
Alkaline	Ossein	150	0.5	0.5
Alkaline	Sinus	150–200	0.5–1	0.5–2
Acid		75–120	0.5–1	0.5–2

Divakaran (1984).

Table 5.11 — Solid waste remaining after extraction filtration or sedimentation in glue production

	Kilogram per tonne of glue	Percentage			Use
		Moisture	Nitrogen	Ash	
Clarified Paste Sludge	30–60		8–12		Fertilizer
Extracted Kittle Residue	100–150	80–85			Fertilizer composted with vegetable matter
Dry extracted Kittle Residue	15–24	10	12–14	5–10	Fertilizer

Divakaran (1984).

In the acid manufacturing of ossein from crushed bones, the effluent is usually alkaline due to the use of lime (CaO) in the recovery of dicalcium phosphate ($Ca_2P_2O_7$). This residue is a valuable source of calcium and phosphorus in animal

feeds. The high degree of temporary hardness caused by dissolved calcium salts is usually the most toxic property. The other properties of the effluent can be found in Table 5.10. The chlorine in this product is at the 5–8% level when dicalcium phosphate ($Ca_2P_2O_7$) is neutralized, but when mixed with the 'ossein-wash' this dilutes the chloride, although not below the 3.5–4% level. This is often collected in solar evaporation ponds.

Fats obtained from bones are variable in quality (see Table 5.12) with the best

Table 5.12 — Fat recovered from glue and gelatine production

Raw material	Properties
Fleshings and trimmings	Fleshing grease or tallow, often impure
Limed stock	Cooked with acid to settle lime soaps
Fresh bones	Best quality from steam- or solvent-extracted green bones, soft tallow, light coloured, low acid, low melting point
Sinews	Often impure
Junk bones	Inferior quality, low yield, dark colour high free fatty acids
Pig feet	Soft white grease
Calves' and cattle feet	Neat's foot, acid, good colour and taste

Committee on Textbooks of the American Meat Institute (1958), Divakaran (1984).

Table 5.13 — Fats obtained from bones during gelatine production

Source	Type of fat
Fresh bones	Light coloured, low acid, soft
Pigs feet	White, soft
Calves' and cattle feet	Pale, golden yellow, Neat's foot oil
Fleshings	Fleshing grease or tallow
Junk bones	Low yield, dark, high fatty acids
Limed stock	Lime soap

quality being obtained from solvent — or steam — extracted green bones and poorer quality from dry bones. The facts may be classified as shown in Table 5.13.

Fats skimmed from settling tanks contain large quantities of extraneous matter. This liquid material is often heated to a temperature of 85–90°C (185–194°F) for 4–6 hours and settling may aid in clarifying the fat. The fat may then be washed with 70°C (158°F) water or with 3% salt water (100°C (212°F) and then rewashed with water) or with 0.03–0.1 citric acid ($C_6H_8O_7$) or with 10% trisodium phosphate (Na_3PO_4) and allowed to settle.

REFERENCES

Bogue, R. H. (1922) *Chemistry and technology of gelatine and glue.* New York, McGraw-Hill.

Cleman, R. A. (1927) *By-products of the packing industry*, Chicago, University of Chicago Press.

Committee on Textbooks of the American Meat Institute, (1958) *By-prodcut of meat packing industry.* Institute of Meat Packing, University of Chicago, Chicago.

Divakaran, S. (1984) *Handbook of glue and gelatine.* Madras, India, Indian Leather.

Eastoe, J. E. (1955) The amino acid composition of mammalian collagen and gelatine. *Biochem. J.* **61** 589.

Gelatine Manufacturers Institute of America (undated) *Gelatine.* Gelatine Manufacturers Institute of America, New York.

Gelatine Manufacturers Institute of America (1964) *Standard methods for sampling and testing of gelatins.* New York.

Gelatine Manufacturers Institute of America (1982) *Gelatine.* Gelatine Manufacturers Institute of America, New York.

Moulton, C. R. and Lewis, W. L. (1953) *Meat through the microscope.* Institute of Meat Packing, University of Chicago, Chicago.

Tourtellotte, D. (1974) Gelatin. In *Encyclopedia of Food Technology.* AVI, Westport, Connecticut.

Veis, A. (1964) *The macromolecular chemistry of gelatine. Academic Press, New York.*

6

Edible tissue from bone

INTRODUCTION

For centuries bones have been used to make soup and gelatine. These processes are described in Chapters 2 and 5 respectively. In recent years labour has become more expensive, and as the fish, poultry and meat industries have attempted to salvage more of the adhering meat left on bones, new separation techniques have been employed. When investigating this problem it is obvious that industries using the different species were motivated by different forces. In the fish processing industry relatively large amounts of meat was lost with the bones on conventional processing. A market for speciality items (e.g. fish sticks, spreads, pastes, sausage, cakes and stuffing) from deboned fish was also developing. In addition to this, some species of fish were not popular for human food because of their boney nature (40 million tons (36.3 metric tonnes)), all of which pointed to the need for an efficient method of separating meat from bone.

In the poultry industry, when consumers shifted from purchasing predominantly whole birds to poultry parts, the back and neck parts were hard to merchandise. Also meat from spent layers (hens that are no longer economically productive for egg production) was usually not worth the cost of the labour required to remove it. Speciality items also opened up a market (e.g. poultry frankfurters, turkey rolls, casserole dishes and traditional sausages) for ground poultry meat. Currently there is more than 182 million kg (400 million lbs) of mechanically deboned poultry produced in the U.S. each year.

In the 1970s, boxed beef began to replace carcass beef and this concentrated large quantities of bones in a few plants. These were available for mechanical deboning. The red meat industry was also losing considerable quantities of meat per carcass (6–10 kg or (13.2–22 lb/beef carcass), 1–2 kg (2.2–4.4 lb/pork carcass)) and the loss was not uniform even within an animal, with irregular-shaped bones in the neck, back and loin areas containing more difficult-to-remove muscle tissue than the smooth leg bones.

Several methods have been developed to separate meat from bone. They include: mechanical separation or deboning machines, pressing meat from bone, techniques

developed to use jets of water or small ice particles to wipe the meat from the bone (this latter procedure has not seen commercial use), extraction with water or dilute acids or alkali, or treatment with proteolytic enzymes.

Mechanically deboned or separated meat is now approved for use in most major meat-producing countries and is being used (mixed or used alone) in ground and comminuted meat products. Very little mechanically separated red meat, however, is currently used in the United States.

MECHANICAL SEPARATION OR DEBONING MACHINES

The mechanical deboning or separation technique produces tissue that at times has been called mechanically separated beef, pork or lamb, mechanically deboned beef, pork, lamb, turkey, chicken and fish, mechanically removed meat, and previously was called mechanically processed (species) product. Two excellent reviews of the mechanically separated product can be found in Advances in Food Research titled *Mechanically deboned red meat* by Field (1981) and *Mechanical deboning of poultry and fish* by Froning (1981). Some of the following information is a summary of these reports.

The technique for muscle separation was developed for the fishery industry in Japan in the 1940s, followed by its use in the poultry industry 10–15 years later. Since both fish and poultry have some similarities, the same type of machines can be used in both industries. Mechanically separated meat was approved for use in the red meat industry in 1978. It is estimated that the U.S. could recover a billion pounds of material per year by this technique. In 1982 labelling regulations were revised and the product could then be labelled mechanically separated beef, pork or lamb.

The early bone separators frequently used for poultry and fish squeezed the underground meat and bone mixture between a rubber belt and a perforated steel drum with the softer tissue passing through the drum perforations into the drum while the harder bones were retained on the outside of the drum. Pressure on the belt can be adjusted for the material being separated and pressure rollers to squeeze the belt and drum together can ensure an even distribution of the tissue on the belt. If red meat is to be deboned by this type of equipment the bone must first be ground.

Another type of mechanical deboner first grinds the bones through a bone cutter and introduces the ground mixture into a screw-driven boning head. The material is pressed (with increasing pressure) towards the purifier of a perforated steel cylinder and the soft muscle tissue passes through the holes (e.g. 0.46 mm (0.018 in)) and the bone particles exit at the end of the head.

Another machine cuts the bones into 15–25 cm (5.9–9.8 in) size, loads the cut bones into a constant-volume chamber containing superimposed rings (1.3×1 mm (0.05×0.04 in)) in the cylinder wall and concentric rings at the end of the cylinder. A high-pressure hydraulic-powered ram piston forces the incompressible muscle through the cylinder openings. This is a batch system which differs from the continuous system previously described.

Other procedures have passed bones through a flaming tunnel (to reduce bacterial numbers), broken bones into 5-cm (2-in) pieces and pressed this tissue twice. The second pressing has higher amounts of bone powder and this is further

processed with liquid and a decanter which separates the bone powder from the deboned meat.

Machines have been built using jets of water or small ice crystals to wipe meat residue from bone, but these are not currently in commercial use.

The structure of mechanically deboned red meat or poultry is a finely ground, paste-like product in which the myofibrils are heavily fragmented. Breaks are observed in the Z or M bands under a microscope and the shearing process affects the length of fibrils and results in spherical- to oval-shaped particles. Mechanically deboned fish has a somewhat coarser texture (preferred) resulting from using a deboner with larger holes causing less ultrastructure alteration. Deboned fish that has been washed and dewatered has a somewhat firmer texture due to this treatment. Texturization has been attempted by high temperature (100°C (212°F)) heating of strands of tissue, which increases the resistance to shear and gives the product a firmer texture. Centrifugation has also been used as a tool to modify functional attributes of mechanically separated meat. Most meat emulsion additives have similar effects on mechanically deboned meat as they have on hand-deboned meat.

The yield for similar raw material in most of these machines can be controlled by selecting the size of the hole openings and regulating the pressure generated during the separation operation.

YIELD OF DEBONED MEAT

A deboner can process up to 907 kg (2000 lb) of deboned product per hour. When meat is mechanically separated or deboned the majority of the adhering meat, some of the bone marrow (Table 6. 1) and small quantities of powdered bone (98% of bone particles in red meat must be smaller than 0.5 mm (0.02 in), normal range in red meat is 0.08–0.11 mm (0.003–0.004 in)) pass through the small openings in the deboner. Most of the bone and connective tissue (only 2–4% collagen remains in mechanically separated meat) does not pass through these openings. The size of the the holes in the deboner and the pressure exerted on the tissue affect the yield obtained. The type of bone (irregular bones are more difficult to clean and consequently more adhering tissue normally remains) and the amount of previous trimming also influence yield. It is assumed that 25–40% of clean-bone weight is bone marrow (Table 6.1). This can be harvested by mechanical deboners. Attached lean (which can not be economically removed by hand boning) and bone marrow from bones is the material salvaged from mechanical deboners. Table 6.1 suggests that 11% of pork carcasses, 15% of beef carcasses and 16% of lamb carcasses is bone and these values would be higher when adhering tissue is included. The yield of various bones can be found in Table 6.2. In addition to the attached lean, the amount of marrow (the largest organ in the body, roughly equal in weight to the liver) in the bone also contributes to the yield, and the marrow levels, which average 2–3% of total body weight or 4–6% of carcass weight, can be found in Table 6.1. Using these two factors an average of 30% recoverable lean and marrow based on commercial bone weight is often used as expected yield for beef, pork and lamb bones. In one-half of this total (total 20% of carcass weight) or 10% of carcass weight is bones that are economically suitable for mechanical separation. It is estimated that an average of 6.5 kg (14.3 lb) of mechanically separated tissue could be obtained from a beef carcass and 1.5 kg (3.3 lb) could be

Table 6.1 — Composition of bone (averages in parentheses)

	Pork (%)	Beef (%)	Lamb (%)	Mutton (%)
Bone (% of live weight)	7.5–12	7–12		
Bone (% of carcass weight)	9–30 (11)	12–30 (15)	13–19 (16)	24–41
Vertebral column, ribs sternum (choice animal) (% of carcass weight)		10		
Ox coxae, scapula (% of carcass weight)		2.7		
Round bones (% of carcass weight)		6.5		
Red and yellow marrow (% of bone weight)		25–40		
Marrow (% of whole body weight)		2–3		
Marrow (% of carcass weight)		4–6		
Marrow volume	25–40	25–40		
Fat in marrow		96		
Ossein in bone		33–36		
Calcium in inorganic matter	37	33–37		
Phosphorus in inorganic matter		15		
Yield of mechanically deboned product	35	25		
Lean of commercially removed bones (% of bone weight)		14–47		
Moisture in bone	43	32–50		
Protein in bone	20.6	20.6–29.0		
Fat in bone	12.4	15.2–22.0		
Ash in bone	21.4	13.0–29.0		

Ledward *et al.* (1983), Mann (1962), Field (1981).

obtained from a pork carcass. The vertebral column, ribs and sternum would be economically suitable for mechanical separation because of large quantities of difficult-to-remove tissue or red bone marrow, which is high in protein. Using available world figures this translates into 2.3 million metric tonne (2.5 million tons) of mechanically deboned red meat that could be added to the world's food supply. It is estimated that the US alone could produce from 300 000 000–500 000 000 kg (660 000 000–1 100 000 000 lb) per year of red meat. Skin on poultry parts often is discarded, but if used to a large extent it also passes through the deboner openings and increases the yield. Mechanical separation converts scarce, good-quality protein that would otherwise be lost into an edible category (since bones that are processed through this equipment yield from 21 to 88% as shown in Table 6.2). This converts

Table 6.2 — Yield of hand-deboned and mechanically deboned tissue

Bone source	Percentage yield	
	Hand-deboned	Mechanical deboned
Butcher hogs		
Ham	25.1	27.1–27.5
Picnic	14.3	21.7
Boston Butt	18.7	22.6
Neck		48.0
Rib		39.5
Sows		
Loin	46.7	51.0
Veal		
Shoulder	16.7	36.2
Frames	37.0	60.8
Back	42.0	63.0
Cow beef		
Rib plate	26.2	32.9
Rump	18.1	26.3
Short loin	25.6	34.0
Choice beef		
Neck	41.3	32.8–48.4
Plate	26.9	28.9
Poultry		
Broiler neck with skin		77.5
Broiler back with skin		88.2
Turkey back		80.0
Parts		55–70
Fish		
Trimmings		37–60
Filleting techniques		25–30

Field *et al.* (1976), Protecon Meat Recovery System (undated), Miyauchi and Steinber (1970).

the tissue adhering to bones, that would otherwise go to inedible rendering, into a substantial portion of edible tissue, and the residue is still suitable for rendering.

The bone residue from mechanically deboning has also been evaluated as a protein (15–20%) and mineral (7–15%) source for animal and human diets. Protein isolates have been obtained by sodium maleate ($NaC_4H_3O_4$) and sodium chloride (NaCl) extraction of this residue.

CHEMICAL COMPOSITION

Mechanically deboned or separated meat contains more bone marrow, powdered bone and less connective tissue when compared to hand-deboned meat; therefore,

mechanically deboned meat's chemical composition is different (see Tables 6.3 and 6.4) from its hand-separated counterpart. With some species the tissue is exposed to water prior to deboning, and in some cases more skin is included, which also alters the composition. The composition of mechanically deboned meat also varies considerably due to the age of the animal, bone: meat ratio, cutting methods, skin content, deboner setting (with some machines high yield increases bone and fat content in the separated tissue and causes higher temperatures) and possible protein denaturation. It is estimated that clean bones may contain as much as 24–40% marrow. Much of this is harvested by mechanically separating or deboning. This is the major reason that yields from mechanical separation exceed hand-boned yields.

The fat content of red bone marrow varies between bones, and increases with animal age (cervical and lumbar marrow respectively represent for veal 6.6 and 8.4% fat, steer 16.2 and 46.4%, cow 36.5 and 47.8%) and is different between species. This causes the fat content in mechanically deboned meat to be substantially higher and the protein content to be slightly lower in mechanically separated or deboned meat when compared with hand-deboned meat. Bones with the most adhering meat yield mechanically separated meat with the most protein, and bones with the least adhering meat yield mechanically separated meat with the least protein and the most fat. Mechanically deboned tissue normally has higher quantities of sarcoplasmic and non-protein nitrogen, approximately the same amount of myofibrillar protein and lower stroma protein than similar hand-separated tissue.

Deboning machines also produce a tissue that is two to three times (a greater increase in young animals due to less calcification) higher in haemoglobin (the major pigment in marrow), with no change in myoglobin content, contains two to three times more iron (due to increased haemoglobin) and appears 25–30% darker red than the comparable hand-deboned product. Bone is low in iron (0.01%) but red bone marrow contains 9–23 mg of iron per 100 g or 0.09–0.23% (a large portion of this iron is in the haem form which is absorbed by the human body at a very rapid rate), which results in 4–6.5 mg iron/100 g, or 0.04–0.065% of mechanically separated meat. The quantity of red bone marrow changes with the anatomical location of the bone. Ascorbic acid (vitamin C) in bone marrow (24 mg/100 g or 0.24% in marrow and 2.5 mg/100 g or 0.025% in mechanically deboned meat) also aids in the absorption of iron in the diet. The iron available to the human is often inadequate during infancy, during periods of rapid growth, in the female during the reproductive period and in pregnancy. The recommended intake is from 10 to 18 mg or 0.000352 to 0.000635 oz iron/day.

Mechanically separated or deboned meat also has a higher ash content (Table 6.5) than its hand-boned counterpart. The level varies with age of the animal (older animals have more calcification and the bones contain more ash; the bones are harder and are more easily fragmented in the deboning machine, which increases the ash level in the deboned tissue). Also affecting ash content is species and deboning temperature. Cold-boned meat is higher in minerals than pre-rigor (hot) boned meat and cooked spent layer frames are higher in protein and lower in fat; cooking also gelatinizes collagen which increases the protein. The ash level also increases with yield, which is usually caused by larger holes in the machine and/or if more pressure is exterted on the tissue. If the yields are increased by increasing the pressure the calcium content also increases. Type of equipment (press machines usually have less

Table 6.3 — Composition of hand-separated and mechanical deboned meat

Bone source	Percentage of fresh weight									
	Dry matter		Ether extract		Crude protein		Ash		Calcium	
	Hand	Mechanical	Hand	Mechanical	Hand	Mechanical	Hand	Mechanical	Hand	Mechanical
Butcher Hogs										
Ham	50.39	54–55	27.99	39–42	15.67	10–11	0.54	4.07	0.029	1.39
Picnic	42.25	55.59	22.29	42.37	19.17	9.06	0.68	3.68	0.043	1.22
Boston Butt	38.24	43.15	12.78	26.04	19.21	13.50	0.86	2.71	0.079	0.73
Neck		40–46		25–30		12–15				
Sow										
Loin	45.73	46.15	23.49	29.53	16.72	14.01	0.72	1.77	0.037	0.41
Veal										
Shoulder	24.33	26.27	3.06	7.56	20.23	12.85	0.92	5.36	0.035	1.76
Frame	26.68	26.64	5.57	6.79	18.86	17.57	0.92	2.59	0.045	0.71
Back	24.29	24.21	3.69	5.81	18.69	15.98	1.05	2.21	0.042	0.54
Cow beef										
Rib, plate	47.97	50.33	31.65	31.87	14.16	12.98	0.81	4.59	0.013	1.55
Rump	33.43	58.06	11.85	41.89	17.56	10.05	0.80	4.35	0.083	1.55
Short loin	43.42	50.97	22.52	33.38	16.38	11.62	0.98	4.35	0.014	1.50
Choice beef										
Neck	30.16	35.13	8.99	10–24	19.33	16–17	1.05	3.43	0.056	1.06
Plate	51.89	49–70	27.92	40–50	13.20	9–12	0.50	4.35	0.051	1.49
Poultry bones										
Broiler, neck										
with skin	—	34.00	—	21.80	—	11.50	—	0.70	—	0.03
skinless	—	28.30	—	7.90	—	15.30	—	—	—	—
Broiler, back										
with skin	—	34.50	—	20.20	—	13.70	—	0.60	—	0.04
skinless	—	37.60	—	21.20	—	13.20	—	—	—	—
Spent layers	—	35–40	—	18–26	—	13–15	—	—	—	—
Turkey backs	—	27.6	—	11.70	—	14.80	—	1.10	—	0.06
frames	—	27–30	—	12–14	—	12–16	—	—	—	—
Fish	18.8	22.50	1.20	3.60	19.50	1.00	1.10	—	—	—
Sole	—	16–23	—	2–8	—	12–14	—	1.3–21.	—	—
Rockfish	—	23–27	—	7.5–8	—	14.5	—	1.6–2.0	—	—
Cod	—	17–20	—	2–4	—	14–15	—	1.3–1.5	—	—

Strange R. (personal communication), Protection Meat Recovery System (undated), Field *et al.* (1976), Froning (1970), MacNeil *et al.* (1978), Froning *et al.* (1971) Grunden *et al.* (1972), Froning and Johnson (1973), Webb *et al.* (1976), Crawford *et al.* (1972), Goldstrand (1975).

Table 6.4 — Average compositions of mechanically deboned meat after normal trimming

	Beef bone (%)	Pork bone (%)
Protein	15	13
Fat	25	28
Moisture	58	58
Ash	1–2	1–3
Hard bone residue		0.27 ± 0.06
100–1000 μm		90.6% of hard bones
1000–2000 μm		7.6% of hard bones
2000–3000 μm		1.1% of hard bones
>3000 μm		0.6% of hard bones
Haem, mg/kg	500[a]	300[a]

[a] Normal meat, 250 mg/kg
Bengtsson and Holmqvist (1984); Bijker *et al.* (1979).

Table 6.5 — Mineral composition of mechanically separated tissue

Mineral	Pork	Beef
Ash (%)	0.89–1.77	1.12–2.36
Phosphorus (%)	0.157–0.292	0.165–0.241
Calcium (mg %)	85.25–291.18	204.32–621–54
Magnesium (mg %)	13.75–32.37	15.96–27.07
Sodium (mg %)	109.30–240.02	107.84–198.32
Potassium (mg %)	252.37–465.20	267.34–475.30
Iron (mg %)	4.54–9.88	5.11–9.21
Zinc (mg/kg)	12.00–24.11	11.53–24.11
Nickel (mg/kg)	0.11–0.68	0.18–0.75
Cobalt (mg/kg)	0.03–0.33	0.06–0.51
Copper (mg/kg)	0.18–3.25	0.44–3.08
Tin (mg/kg)	0.64–1.92	0.79–3.02
Lead (mg/kg)	0.00–1.20	0.00–1.51
Cadmium (mg/kg)	0.00–0.07	0.00–0.06
Antimony (mg/kg)	0.00–0.73	0.00–1.46
Selenium (mg/kg)	0.00–0.08	0.00–0.16
Arsenic (mg/kg)	0.00–0.45	0.00–0.51
Mercury (mg/kg)	0.00–0.15	0.00–0.20

Djujic *et al.* (1979).

than 0.4% bone powder, but the bone particles are normally larger) and method of operation of the deboner also influence the mineral content in mechanically deboned tissue. Fat is lower in calcium and ash than lean tissue; therefore, the fat : lean ratio also influences the calcium and ash level.

The phosphorus level is not drastically different in mechanically deboned and hand-deboned meat. The dry fat-free bone is approximately 12% phosphorus, but the additional phosphorus obtained from the bone is diluted with fat, which is low in phosphorus (10 mg/100 g or 0.1%) in mechanically separated meat. Magnesium is the next most abundant mineral in dry fat-free bone but it, like phosphorus, is also diluted by low magnesium content in fat.

The ash in mechanically separated tissue is primarily calcium. The calcium level can be used to indicate the bone level, which again can be controlled by yield and the amount of meat left on the bone prior to deboning (diluted by increased adhering tissue).

Calcium is normally low in the human diet, with most people over 35 consuming only two-thirds of the recommended daily allowance (800 mg (0.028 oz) calcium/day for adults and 1200 mg (0.042 oz)/day during gestation). If an individual consumes an excess of calcium no detrimental effects are observed. Bone powder also supplies many other minerals essential for normal human nutrition. The retention of calcium from cooked ground bones is estimated to be approximately 90% of that found with whole dried milk. The bone source of calcium is especially useful for those people who have a lactase deficiency and cannot tolerate milk as a calcium source. Other bone mineral components such as lead, fluorine and strontium-90 also increase with bone (ash or calcium) levels. However, strontium-90 has not been detected in bones in the last 5 years and lead levels are very low. Since some people cannot tolerate calcium, the USDA limits the calcium level of mechanically separated red meat to 0.75% (not more than 3% bone content) or uses a maximum tolerance of 0.90% of calcium on a single analysis basis and a bone content based on a maximum of 1% calcium in poultry used in meat products. The calcium levels are often multipled by a factor of four (USDA) to obtain an estimate of the percentage of bone in mechanically deboned product. In addition to percentage of bone, the particle size is also important, since large particles will cause the tissue to have a gritty texture. Therefore, in addition to chemical analysis, bone size is also regulated (USDA) in red meat; 98% of the bone particles may have a maximum size, in their greatest dimension, of no greater than 0.5 mm (0.02 in), and no particles of bone powder may have a dimension greater than 0.85 mm (0.03 in). A machine with 0.46 mm (0.018 in) openings will normally yield bones with a mean diameter of $900 \pm 200\ \mu m$ (0.035 ± 0.008 in), which is not organoleptically objectionable but does exceed the current USDA limits. Mechanical deboning ensures that large bones (of a size that can chip teeth) are not present, but these may be in hand-separated products. Excessive fluoride reduces tooth decay but may cause mottling of children's teeth, and therefore mechanically separated meat is limited to 20% of a meat or poultry product and mechanically deboned red meat may not be used (in U.S.) in baby or junior foods. The additional calcium and iron in mechanically separated meat is readily absorbed by humans. These minerals are traditionally low in most diets; therefore, the nutritional value of this tissue in mineral levels exceeds and is superior to the levels in hand-deboned products. It is recommended that kidneys be removed

from mature poultry prior to deboning, since they may contribute unwanted cadmium to the product. The Dutch regulations for exported mechanically deboned product have a maximum level of 1% bone and 0.25% calcium, with no bone particles larger than 1 mm. The Canadian Government allows larger bone particles in mechanically separated meat. Their regulation states that 98% must be less than 0.84 mm (0.033 in) and that 100% must be less than 2.0 mm (0.079 in). Some European countries have more liberal bone size standards than Canada. If the bones are processed through a cutting rather than a grinding procedure and then through the batch-processing technique, the ash or bone level will be very similar to that of hand-deboned meat.

Most mechanically separated meat exceeds (see Table 6.6) the minimum

Table 6.6 — Protein efficiency ratio (PER) for rats

Protein source	PER (g gained/g protein eaten)
Casein (for red meat data)	2.97
Beef, semimembranous	2.91
Choice beef plates	1.90
Cow rib bones	1.44
Veal bones	2.67
Lamb neck bones	2.90
Pork neck bones, regular	2.60
Pork neck bones, close trim	2.00
Casein (for poultry data)	2.50
Chicken back and neck	2.34
Cooked poultry meat	2.41
Turkey frame	2.59

Field *et al.* (1979), Babji *et al.* (1980).

(USDA) level of 2.5 protein efficiency ratio (PER, high protein quality) and 33% essential amino acids. PER values can be raised in mechanically separated meat by staying below the maximum (USDA) calcium level (0.75%) or by leaving more lean meat on the bone prior to deboning. The protein quality is of concern since bones from the cutting room contain a large quantity of adhering collagen; the bone itself contains 25% collagen. This pattern is not considered to be well balanced in amino acid composition. These concerns are reduced, however, when it is realized that much of the connective tissue, as well as bone, is removed during mechanical separating or deboning. Also marrow is a good source of lysine, leucine and histidine, which are essential and often limiting amino acids in many diets. Not only does the PER indicate this is not a major problem, but if the percentage of the eight essential amino acids for hand-deboned meat (35–40%) is compared with those for mechanically separated meat (24–42%) it can be seen that in most products the

percentages are similar, but more variability is encountered in the mechanically separated meat. Since some connective tissue is removed and some bone powder and marrow are added to mechanically separated meat, the protein quality between control tissue and mechanically separated meat is similar. The discarded bone from mechanical deboning is an inferior product from a protein quality standpoint, having only 28% essential amino acids and a PER value of less than 0.5.

The maximum allowable (USDA) fat level for one category of mechanically separated meat is 30% and the minimum protein level is 14%. There is no protein or fat limit in a second category, where the mechanically separated meat is to be used in a meat product that has inspection limits. Bone marrow lipid contains more polyunsaturated fatty acids, more phospholipids and more cholesterol than do lipids from subcutaneous or intramuscular fats. With the increase in fat in most mechanically separated meat, this also translates into an increase in these components. The cholesterol level of mechanically separated red meat is fairly similar to that of hand-deboned meat, but in poultry the cholesterol level is approximately doubled because of the presence of the spinal cord in the bone.

The RNA value and the purine content of mechanically deboned meat is in the same range as hand-deboned meat, but the DNA values exceed those of hand-deboned tissue because of the inclusion of bone marrow. The pH is also higher in mechanically separated meat than in hand-deboned meat.

The water-binding capacity, emulsifying ability, cooking stability, cooking yield and loaf size of mechanically separated meat is good when used in a sausage emulsion product. As the level of skin increases, there is a slight decrease in emulsion stability and emulsion capacity per gram of meat, probably due to increased fat.

MICROBIOLOGICAL QUALITY

To produce mechanically separated meat with good microbiological quality it is essential that the bones prior to deboning be handled in the same manner as fresh muscle tissue. This means sanitary handling, low temperatures and limited storage must be maintained (utilizing pre-rigor bones from hot boning is preferable). Mixing of external tissue (more highly microbiologically contaminated) with cleaner internal tissue, a temperature rise of 1 to 6°C (1 to 10°F) during grinding and 5 to 8°C (10 to 15°F) in some deboners during processing and fine grinding makes this separated tissue an ideal growth media for microorganisms.

It is recommended (USDA) that bones from hand-boned chilled carcasses be mechanically processed (separated or deboned) within 1 hour, stored at 4°C (40°F) if processed within 72 hours, or frozen at −18°C (0°F) if processed in excess of 72 hours. If hot-boned tissues are used, they should be processed within 4 hours of slaughter, stored at 4°C (40°F) if they are to be processed within 72 hours, or frozen to −18°C (0°F) if they are to be processed in excess of 72 hours. In Denmark fresh chilled bones are used for deboning and the product is immediately chilled to 3°C (37°F) or lower. The mechanically separated tissue must be used in 24 hours or frozen to −18°C (0°F) or lower. The Australian government states that bones must be handled and processed in a hygienic manner and kept cold prior to deboning or frozen if held longer than 36 hours prior to deboning. Mechanically separated tissue must be reduced to 7°C (45°F) within 2 hours of processing and used within 24 hours

or must be frozen. During mechanical separation both the grinding and deboning processes raise the temperature; this temperature rise is more severe with hard bones than with soft bones. If cold bones are used the temperature range out of the grinder may be between −1 and 8°C (30 and 46°F) and out of the deboner between 0 and 38°C (32 and 100°F). These temperatures require effective chilling procedures (blast freeze in 5–7 cm or 2–2.7 in layers) if deboned meat is to maintain its microbiological integrity. If the temperature can be rapidly reduced and maintained at 4°C (39°F) there will be little increase in microbiological numbers in the mechanically separated meat during 24 hours of storage.

OXIDATION

Unsaturated fat (bone marrow fat is more unsaturated than subcutaneous or intramuscular fat), high processing temperature, fine grinding and mixing of bone marrow, incorporation of air and haem pigments, contact of deboned tissue with iron parts of the deboner (most are stainless steel today), all contribute to ideal conditions for fat oxidation which can lead to off flavours and colour deterioration (dull brownish-red) in mechanically separated meat. This seems to be particularly a problem with unsaturated fat from deboned poultry products. The ratio of unsaturated fatty acids to haem protein is often highly correlated to oxidation in mechanically separated meat. Washing of mechanically deboned fish and filtering seems to improve product stability. Oxidation occurs very rapidly above 10°C (50°F) but can still be a problem even at −30°C (−22°F). Oxidation is much less of a problem with separated mutton and beef and intermediate with separated pork due to its larger quantity of saturated fat in the ruminant fat. Incorporation of antioxidants into deboned tissue in some cases might prove useful; however, phenolic antioxidants have not proven to be very satisfactory, probably due to poor solubility in tissue. Chelating agents and polyphosphates have proved useful in some circumstances. Carbon dioxide (CO_2) chilling seems to accelerate oxidation, but is often used to lower temperature and to control microbiological growth. Liquid nitrogen does not appear to stimulate oxidation, while reducing product temperature.

Cellular disruption in fish during mechanical deboning leads to breakdown of trimethylamine oxide (TMAO, linked to fishy odour) to trimethylamine (TMA) or dimethylamine (DMA). The TMA and DMA often increase two to four times in mechanically separated products.

EMULSION PROPERTIES

The added bright-red colour of mechanically separated meat is considered desirable in many processed meat items but, of course, is a negative factor if the processor is striving for a pale to white sausage.

Mechanically separated meat has at least as good an emulsifying capacity (sometimes higher) and water-holding capacity, and slightly higher emulsion stability than its hand-deboned counterpart. Frozen storage time of mechanically separated meat does decrease emulsifying capacity and it appears that the warmer the frozen temperature the more detrimental frozen storage time becomes. The batter viscosity increases with increases in amounts of mechanically separated meat in the

formulation. Bind values are also similar between hand-separated and mechanically separated meat. When mechanically deboned meat is compared to hand-deboned controls no significant differences were found in sausage emulsion products in 'degree of fatting out', ease of peeling and smokehouse shrinkage. Most of these favourable mechanically separated meat properties are attributed to a decrease in connective tissue and an increase in pH for the mechanically separated meat.

The increase of pH of mechanically separated meat is caused by the addition of red bone marrow (pH 6.8–7.4) and could be influenced by the basic calcium phosphate in bone powder. When mechanically separated meat is blended with other tissue this increases its water-holding capacity, which in turn influences emulsion formation, meat processing, storage, cooking and freezing properties. Some of the beneficial effects of increased pH on improved water-holding capacity can be offset by elevated calcium, magnesium, potassium, iron and copper levels in the mechanically separated meat, which exert a negative influence. Freezing, and particularly slow freezing, also decreases the water-holding capacity. If mechanically separated meat is processed under optimum conditions then the water-holding capacity should be approximately equal to that of hand-deboned product.

USES OF MECHANICALLY DEBONED MEAT

Mechanically separated red meat may be added to ground-beef patties, comminuted fresh, smoked, and cooked sausage-type products, stews, sauces, spreads and similar products and even to chunked and formed products (pressed and chopped ham). With mechanically deboned poultry other items are included. The favourable price of mechanically deboned poultry and fish in comparison to other meat sources has made it very popular in 'least-cost' formulated products. The chemical characteristics of marrow improve palatability, texture and juiciness of meat mixes if incorporated at the proper level (this depends on the amount of marrow and bone powder in the mechanically deboned meat). If the proportion of mechanically separated tissue is too large, however, the organoleptic characteristics of the combined products deteriorate. Normally, as deboned meat is incorporated into hand-deboned meat at *high* levels, the flavour and overall acceptability scores will become lower, colour becomes darker (due to haemoglobin in marrow and then reduction of connective tissue, which is devoid of pigments) and the tenderness (often to an unacceptable mushy state in some products) and juiciness scores (10–20% increase) are higher. For these reasons the practical level of incorporation of mechanically separated meat into hand-deboned meat is usually limited. Some levels that have been suggested are: 5–20% (10% often mentioned) in beef patties (not permitted (USDA) in hamburger, ground beef, or fabricated steaks), and 10–40% (20% is considered maximum in the U.S. (USDA) in sausage emulsions but higher levels of low-fat product can be added without organoleptic problems). Mechanically separated meat that has been abused reduces palatability of products in which it is incorporated.

Deboned meat is often combined with textured soy proteins in meat products, and the dark colour and mushy texture of mechanically separated meat are somewhat counterbalanced by the lighter colour and coarse or rubbery texture of the soy product when mixed with meat.

In Denmark, if mechanically deboned meat is used at levels of less than 2% it

does not have to be declared on the label, but if used over the 2% level it is to be declared. In Australia, exported product is labelled 'edible mechanically deboned meat/beef/mutton' and contains a statement of the maximum calcium, moisture and minimum protein content.

In the U.S., two categories of mechanically separated red meats are approved. One has a minimum of 14% protein (running average of 10 analyses) with a 13% minimum protein allowed on a single analysis, and a maximum of 30% fat (running average of 10 analyses) with a 33% maximum of fat allowed on a single analysis. A second mechanically separated product has no protein or fat requirements, but is permitted only in products where the quantity of fat is limited. These products cannot be used in baby food, ground beef, hamburger, fabricated steaks, certain cured pork cuts, meat pies and a few other items, but may be utilized at a level of 20% in beef patties, pressed and chopped ham, a variety of fresh smoked and cooked sausages, stews, sauces, spreads and similar products. The label must declare the calcium content of the finished product if the mechanically separated product constitutes 20 mg (0.0007 oz) or more of calcium to a serving. Due to repeated court hearings and 'bad press' mechanically separated red meat has not been utilized at its maximum potential in the U.S. Only 579 693 kg (1 275 324 lb) of mechanically separated beef, 222 487 kg (489 405 lb) of mechanically separated pork and 211 564 kg (464 441lb) of mechanically separated veal were used in the U.S. in 1982 (Field, 1983).

Bone fragments in this product are so small that they are undetectable in the mouth when this product is eaten, and most experts agree that these constitute no health hazard.

Flavour stability of mechanically deboned meat depends upon species, meat type, composition, age prior to deboning, deboner type and setting, quantity of haem (myoglobin has a greater catalytic effect on oxidation than haemoglobin), contact with metal parts of the deboner and temperature of deboning.

Colour abnormalities (brown, green, grey) have sometimes become apparent during storage of mechanically separated meat. Storage and CO_2 treatment tend to make the tissue darker, and increased fat levels and skin levels tend to dilute the haem pigment. During deboning and mixing of air with tissue, myoglobin is converted to oxymyoglobin, and surface oxidation during storage converts this to metmyoglobin.

OTHER BONE EXTRACTION PROCEDURES

Other methods of separating muscle from bone include liquid extraction and some of these techniques are described in the 'meat extract section' of Chapter 2. Other liquid-separation procedures include tumbling of bones with water in a rotating drum and the removal of water and fat from the extracted material with a centrifuge; however, the aqueous extraction methods have not received wide commercial acceptance.

Another procedure would include a cold alkaline extraction. In this procedure, the bones are ground to 1.5–2.0 cm (0.06–0.08 in) in size, water (H_2O) and sodium hydroxide (NaOH) in a 1.5 : 1 ratio (resulting in a 10.5 pH) are added and the mixture is tumbled to extract the protein. The resulting liquid mixture contains

approximately 2.6% protein, which is precipitated by adjusting the pH to 5.3 and centrifuging the product. The yield of protein is only about 15%, probably due to the technique's inability to precipitate the sarcoplasmic proteins. The yield (up to 90%) can be increased by heating (80°C (176°F), pH 5–6) the liquid, but this denatures the proteins and reduces their functional properties making them gritty and uncohesive. The non-heated extract contains approximately 13% protein, has a texture like minced veal (a firmer texture can be obtained by a freeze (−30°C (−22°F)–thaw treatment at pH 6.5) and is bland, lacking the typical meat flavour. The PER for protein from low-temperature alkaline extracts is comparable to lean beef.

Flavouring ingredients have been extracted from bones for many years in the Orient. In this process, crushed bones are combined with water and cooked under pressure (4 kg/cm^2 or 57 lb/in^2) for 1.5–2 hours. The product is cooled and the fat is skimmed from the liquid. This technique yields 66% liquid extract, which contains approximately 10% solids (salt is sometimes added to raise the solid level to 15%). This process can be modified by adding steam instead of water and cooking at 6 kg/cm^2 or 85 lb in^2 for 2 hours. This will yield a 43% liquid extract with 20% solids. An alternative process is a hot-water extraction for 20–40 hours, which yields 66% liquid extract with a 5% solid concentration. All of the products can also be vacuum concentrated to 60% solids.

These extracted products have been used as a soup base, in noodle products, sauces, stews and curries as well as in processed hams and sausages. Some have also been used to manufacture a hydrolysed animal protein (HAP) flavouring ingredient.

Another European technique, starting with the residue from mechanically separated meat or with regular bones, sends them through a defatting process, and then routes the bones through an acid or a centrifuge-cooking process to extract edible bone protein (see Fig. 6.1). This process yields fat, and the acid process yields dicalcium phosphate and edible bone collagen. The cooking process yields edible bone phosphate and soluble bone protein. This extraction technique has the advantage of starting with the residue of mechanically deboned tissue and extracting additional edible protein from this tissue. The first step is defatting, which consists of crushing (to 7–10 mm (0.3–0.4 in)), washing with hot water and centrifuging the bone. This hot-water countercurrent washing system removes the fat and the fat–water system is separated by a disc centrifuge. The recovered fat is grade 1 and yields of 10–14% of the fresh bone weight are obtained. The defatted bone contains less than 2% fat on a dry-weight basis.

The defatted bone is treated with dilute hydrochloric acid (HCl) which dissolves the mineral portion (mainly hydroxyapatite) and leaves the collagen undissolved. This is accomplished with a three-stage countercurrent operation with subsequent washing of the protein and adjustment of the pH to 4–5. The edible bone-collagen protein is dewatered by centrifuging and the dried material (90% protein) is then milled. This procedure, of course, is very similar to the making of ossein from bone (see Chapter 5). The spent acid is then treated with a lime slurry and this precipitates dicalcium phosphate, which is vacuum filtered and dried. The dicalcium phosphate yield is approximately 25% of the raw-bone weight and is used in animal feed as a source of calcium and phosphate.

The edible bone collagen has little taste or odour, is not soluble in water but does swell, has good fat and water absorption in cold water, and, due to the acid

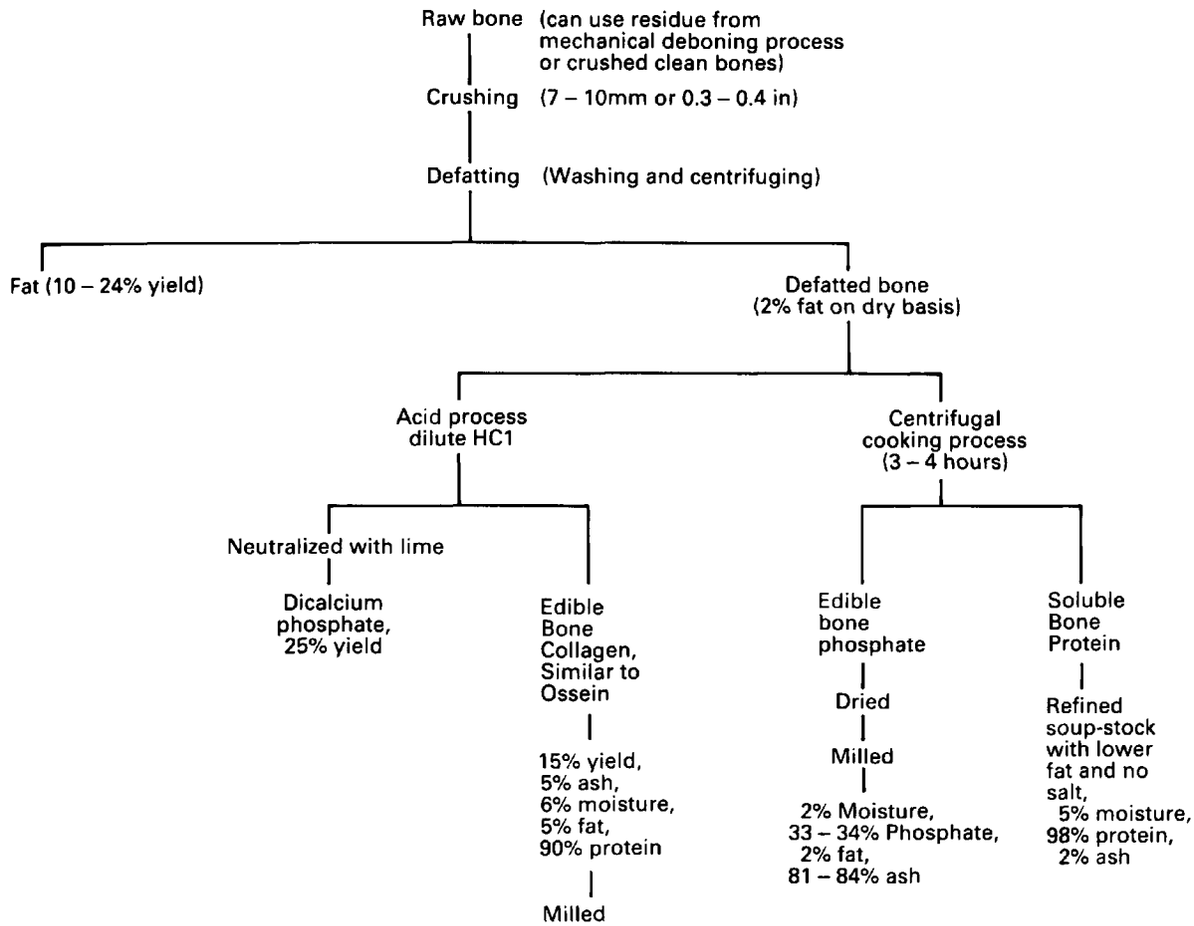


Fig. 6.1 — Liquid separation of edible protein from bone (USDA, undated).

treatment, is low in bacterial numbers. It may be used (where local laws permit) in many comminuted meat products, and has good absorbing properties (for fat and water). This product tends to give meat a more crumbly and less chewy texture.

The previously described defatted bone may also be cooked in a low-speed basket centrifugal cooker and the superheated water leaches the extract from the bone mass. Three to 4 hours of extraction time are needed to hydrolyse the protein. The hydrolysate is evaporated and spray-dried to give a stable soluble bone-protein powder.

The remaining edible bone phosphate consists mainly of the mineral hydroxyapatite with some carbonate–apatite and fluoro-apatite and residues of unextracted protein and fat. It is approved as a food additive in the UK. It is used as a source of the correct ratio of calcium and phosphorus in foods and is normally added at a 0.5–2% rate.

Soluble bone protein (95% protein) is similar to bone gelatin hydrolysate, except it is obtained by direct natural hydrolysis without the utilization of an acid or alkali. Consequently it is very similar to soup stock, except that it has a low fat content and no added salt. Soluble bone protein is soluble in water but does not bind water or form a gel. Soluble bone protein is used in soups, sauces and gravies and as a protein supplement to meat products.

Liquid–extracted tissue differs greatly from mechanically separated or deboned products and has not been as commercially popular.

INEDIBLE USES OF BONES

Bones are, of course, also used for inedible purposes. This has been discussed in more detail in Chapter 3, but a brief summary is given in Table 6.7.

Table 6.7 — Processing of bones for inedible uses

Bone and meat meal	Bones, adhering meat and tendons processed under pressure with other offal
Raw bone meal	Bones are boiled to remove adhering material and part of ossein and are then milld
Steamed bone meal	Bones are boiled under pressure to remove ossein and milled
Meat meal	Bones are boiled under pressure and the freed ossein used
Calcified bone or bone ash	Bones are burned for 30 minutes to 1 hour and then powdered
Bone char	Bones are ground to 2–5 mm (less than $\frac{1}{4}$ inch), heated to 500–700°C (932–1292°F) for 4–6 hours. Bone oil is a by-product of this process.
Bone china	Similar to bone ash but made in the absence of any metal container. Pig bones are unsuitable

REFERENCES

Alfa-Laval, (1979) *Process innovations for the meat by-products industry.* Stockholm, Sweden, Alfa-Laval.

Babji, A. S., Froning, G. W., and Satteslee, L. D. (1980) *The protein nutritional quality of mechanically deboned poultry meat as predicted by C-PER assay. J. Food Sci.* **45** 441.

Bengtsson, O. and Holmquist, O. (1984) *By-products from slaughtering. Fleischwirtschaft* **64** 1–4.

Bijker, P. G. H., Gerats, G. E., Van Logtestijn, J. G., Koolmees, P. A. and Fransen, T. (1979) Methods to determine the bone content and the size of bone particles in mechanically deboned pork. *Proc. Eur. Meat Res. Work., 25th.* p. 845.

Crawford, D. L., Law, D. K. and Babbitt, J. K. (1972) *Nutritional characteristics of*

marine food fish, carcass waste and machine separated flesh. J. Agric. Food Chem. **20** 1048.

Djujic, I., Djoudjevic, V., Mihajlovic, B. and Radovic, N. (1979) *Mineral components of mechanically separated meat. Proceedings of the 25th European Meat Research Work Conference*, p. 859.

Field, R. A. (1981) *Mechanically deboned red meat. Advances in Food Research* **27** p. 23. New York, Academic Press.

Field, R. A. (1983) *An update on mechanically separated meat. Proceedings of the 36th Annual Reciprocal Meat Conference*, p. 38.

Field, R. A., Kruggel, W. G. and Riley, M. L. (1976) *Characteristics of mechanically deboned meat, hand separated meat and bone residue from bones destined for rendering. J. Animal Sci.* **43** 755.

Field, R. A., Chang, Y. O. and Kruggel, W. G. (1979) *Protein quality of mechanically processed (species) product and bone residue. J. Food Sci.* **44** 690.

Froning, G. W. (1970) *Poultry meat sources and their emulsifying characteristics as related to processing variables. Poult. Sci.* **49** 1625.

Froning, G. W. (1981) *Mechanical deboning of poultry and fish. Advances In Food Research*, **27** p. 109. New York, Academic Press.

Froning, G. W., and Johnson, F. (1973) Improving the quality of mechanically bedoned fowl meat by centrifugation. *J. Food Sci.* **38** 278.

Froning, G. W., Arnold, R. G., Mondigo, R. W., Neth, C. E. and Hastung, T. E. (1971) Quality and storage stability of frankfurters containing 15% mechanically deboned turkey meat. *J. Food Sci.* **36** 974.

Goldstrand, R. E. (1975) Mechanically deboned meats — yield and product characteristics. *Proceedings of the 28th Reciprocal Meat Conference* p. 116.

Grunden, L. P., MacNeil, J. H. and Dimick, P. S. (1972) Poultry product quality: chemical and physical characteristics of mechanically deboned poultry meat. *J. Food Sci.* **37** 247.

Ledward, D. A., Taylor, A. J. and Lawrie, R. A. (1983) *Conversion of bone to edible products.* In *Upgrading waste for feeds and food.* London, Butterworths.

MacNeil, J. H., Mast, M. G. and Leach, R. M. (1978) Protein efficiency ratio and levels of selected nutrients in mechanically deboned poultry meat. *J. Food Sci.* **43** 864.

Mann, I. (1962) *Animal by-product processing and utilization.* FAO Animal Production and Health Series, No. 9, FAO Agricultural Development Paper No. 75, Rome, Food and Agriculture Organization.

Miyauchi, D. and Steinberg, M. (1970) Machine separation of edible flesh from fish. *Fish Ind. Res.* **6** 165.

Protecon meat recovery system, (undated) Holland, Protecon.

USDA, (undated) *Memorandum of screening and surveillance* Vol. 111, No. 3 Washington D.C., Food Safety And Inspection Service, USDA.

Webb, N. B., Hardy, E. R. Giddings, G. G. and Howell, A. J. (1976) *Influence of mechanical separation upon proximate composition functional properties and textural characteristics of frozen Atlantic croaker muscle tissue. J. Food Sci.* **41** 1277.

7

Medicinal and pharmaceutical uses of by-products

ANIMAL GLANDS

Animal glands have been consumed as described in Chapter 2 since recorded history. Some of them have been used in medicine for their healing powers (actual or 'magical' in some societies). Throughout the body there are a number of internally secreting, ductless glands called endocrine glands that secrete hormones, whose under- or over-production can cause drastic changes in the body (see Fig. 7.1). These

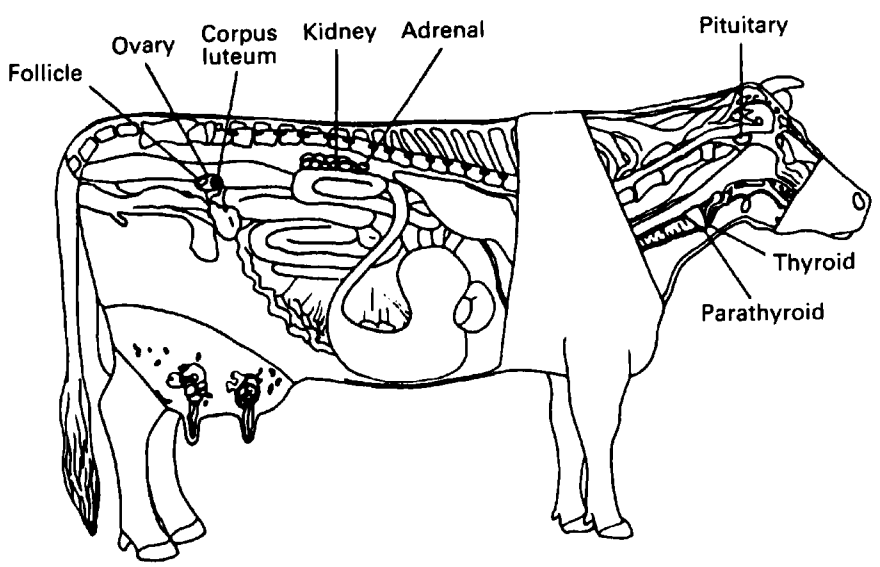


Fig. 7.1 — Endocrine glands of the dairy cow. The same endocrine glands are present in other females of different mammalian species. They are also present in the male, except that it is the testicle that is functional. (Missouri Agricultural Experimental Station, 1963).

glands, saved in larger progressive meat plants for pharmaceutical uses, account for only approximately 0.28% of the animal's live weight. Digestive enzymes which are also useful in the medical and pharmaceutical area (see Table 7.1) are obtained from

Table 7.1 — Yield of gland products

Gland	Number of glands per pound[a] fresh	Number of animals per pound[a] fresh	Number of glands per pound[a] of finished product
Bile, beef (liquid)	2–4	2–4	
Bile, beef (75% solids)		20–30	
Ovary (cow)	70–100	35–50 cow	200–600
Ovary (cow) (corpus luteum)	80	40 cows	1600
Ovary (hog)	90–145	45–145 (sow)	275–864
Ovary (sheep)	600–1400	300–700 (ewe)	3600–8400
Pancreas, beef	2	2	13 000–24 000
Pancreas, pork	6–10	5–10	60 000–120 000
Parathyroid	450–600	Av. 300 cattle	1800–3600
Pineal (beef)	1800	1800	12 600
Pituitary (beef)	148–185	148–185 cattle	740–1060
Pituitary (beef)			10 000–18 000 for ACTH
Pituitary (pork)	1700–1800	1700–1800	400 000–1 152 000 for ACTH
Pituitary posterior	148	148 cattle	10 000–18 000
Stomach (pork) (pepsin)	3–4	3–4	18–20
Suprarenal (adrenal), beef (epinephrine)	32–50	16–25	114
Testicle, beef	2	1	6
Thyroid (beef)	20	20	100

[a]1 lb=454 g.
Moulton and Lewis (1953), Mann (1962), Romans *et al.* (1985), Ockerman (1975), National Live Stock and Meat Board (1975, 1977), Maurer (1951), Committee on Textbooks of the American Meat Institute (1958).

the red portion of the stomach lining around the pylorus (pepsin), and obtained from the fourth stomach of the calf (rennin) and from the pancreas (diastase (amylase), lipase and trypsin).. These hormones and enzymes, along with vitamins, food supplements and other biological chemicals are often collected and derived from animal by-products collected for that purpose (Tables 7.2, 7.3) at the slaughter industry level.

Different animals have different glands that are important and this is determined by the species, sex and age of the animal. The weights of these glands for beef, sheep

Table 7.2 — British collection of by-products for pharmaceutical use

Material collected	Percentage of meat plants collecting
Gall	22
Suprarenal	Approx. 4 (cattle only)
Pituitary	12
Thyroid	12 (cattle), 0 (pig), 0 (sheep)
Mucus from intestine	12
Ovaries	0
Spinal cord	12 (for pet food)

British Food Manufacturing Industries Research Association (1978).

Table 7.3 — Response of 11 U.S. firms to questionnaire on salvaging of by-products for pharmaceutical use

Tissue	Beef		Pork		Lamb	
	Saving (%)	Not saving (%)	Saving (%)	Not saving (%)	Saving (%)	Not saving (%)
Adrenal	37	62	18	82	0	100
Bile	100	0	18	82	0	100
Blood (live animal)	—	—	—	—	0	100
Colostrum	16	83	—	—	—	—
Duodenum	0	100	—	—	—	—
Foetal blood	88	11	0	100	—	—
Gall bladder	14	85	0	100	—	—
Gall stone	66	33	0	100	—	—
Heart	—	—	—	—	0	100
Heart valve	—	—	36	64	—	—
Kidney	—	—	—	—	0	100
Lungs	42	57	18	82	0	100
Mucosa	—	—	9	91	—	—
Ovaries	42	57	18	82	0	100
Pancreas	100	0	82	18	20	80
Parathyroid	14	85	—	—	—	—
Pepsin	—	—	27	73	—	—
Pineal	14	85	0	100	—	—
Pituitary	—	—	36	64	0	100
Pluck	—	—	—	—	0	100
Pregnant utera	—	—	—	—	0	100
Rennet	—[a]	—	—	—	0	100
Skin	—	—	9	91	—	—
Spinal cord	0	100	—	—	—	—
Testicle	14	85	—	—	—	—
Thyroid	14	85	9	91	0	100
Xiphoid cartilage	0	100	—	—	—	—

[a]Beef plants.
University of Illinois and National Livestock and Meat Board (1986).

and hogs are summarized in Table 7.4. The glands are collected only from healthy animals, and the location of the gland requires experience since some of the glands are often small and are often encased in other tissue. Some glands are more perishable than meat cuts and must therefore be handled quickly in order to retain their 'principle' (activity), which is necessary for their ultimate pharmaceutical use. This requires that glands be quickly excised from the slaughtered animal to reduce exposure to high temperature (prompt chilling) and water spray. Small glands are placed in glass or metal buckets with holes to allow drainage. The buckets also contain ice, or in some cases dry ice, for chilling (especially for pituitary and suprarenal glands), but the glands are not allowed to contact the ice since some of the hormones would be extracted by water. Large glands may be collected quickly and go directly to the cooler at frequent intervals. Some glands (e.g. pituitary, ovary and corpus luteum) must be divided into their distinctive parts. This is usually a delicate and precise hand operation (some machinery has been developed to aid in this procedure). The best method of preserving most glands to retard autolysis and destructive bacterial growth is by quick freezing, but some glands can also be preserved by chemical means (e.g. 1 part gland to 1 part acetone (C_3H_6O) or 1 part phenol (C_6H_6O) or 2 parts formalin (37% CH_2O)). The next step usually involves cleaning and trimming of surrounding fat and connective tissue and making sure to save the portions of the gland that are richest in the desired substance. Within an hour of removal from the carcass, the glands should be placed, spread out for faster freezing and not touching so that single glands may later be hashed without thawing, on a clean, prechilled tray or on waxed paper and put into a sharp freezer −18°C (0°F) or less; never above −9°C (15°F). Within 48 hours the hard frozen glands should be removed from the trays and placed in covered containers to minimize contact with air and prevent freezer burn. They remain frozen until processed by the pharmaceutical manufacturer. Properly handled and frozen glands should be bright pink in colour with the exception of the suprarenal gland which should have a light brown colour. Under no circumstance should the glands be permitted to thaw, since freezing breaks some of the cell walls and, if thawing is permitted, destruction of the active principle (activity) often occurs.

When the glands arrive at the pharmaceutical plant they are again inspected, hashed in a hard frozen state in a meat chopper, received in a suitable solvent, such as water for liver extract, or acidulated alcohol for insulin production, or spread on non-corrosive (Monel Metal, glass or enamel) pans usually for vacuum drying. Some hormonal concentrations, such as ACTH (adrenocorticotrophic hormone), will maintain their full strength in the dry state, but rapidly lose their potency in water solutions. Drying, vacuum drying (most popular), spray drying and freeze drying are also sometimes used. Vacuum drying allows drying at a temperature low enough to prevent coagulation of protein and also low enough not to destroy the heat-sensitive pharmaceutical value. The pans are placed in 'shelf vacuum driers' at a temperature that will not destroy the active principle or activity (usually 24–32°C (85–90°F), using heated water as a heat source, not hotter than 54°C (130°F) and at a pressure reduced to usually 0.7 kg/cm^2 (10 lb/in^2) to dry the glands. With some extremely heat-sensitive, highly purified extracts, such as anterior pituitary hormones and suprarenal cortex extracts, high-vacuum freeze-drying (lyophilizing) is used. Some manufacturers dry glands, especially the pituitary, by placing them in successive portions of

Table 7.4 — Weight[a] of glands or tissues

Portion	Beef	Sheep	Hog
Adrenal	15–30 g	2–3 g	3–5 g
Blood	19–40 lb	3.5 lb	5–10 lb
Bones and muscles	560–600 lb	37–43 lb	160–175 lb
Brain and cord	20–26 oz	6–9 oz	10–16 oz
Gall	300–400 g (9% solids) Calf 10–40 g (8% solids)	25–30 g (9–11% solids) Lamb 15–23 g 10–12% solids)	28 g
Heart	3.5–7.1 lb	0.4–0.6 lb	0.5–1 lb
Kidney	0.5–1.5 lb	3–4 oz	0.17–0.8 lb
Liver	9–14.5 lb	1–2 lb	2–4.6 lb
Lungs	4–8.1 lb	0.5–2 lb	1–2 lb
Ovary	5–20 g	1.5 g	3–10 g
Pancreas	0.3–1.6 lb	0.8–1.5 oz	1.5–4.2 oz
Parathyroid	0.4–2 g	0.2 g	0.15 g
Pineal body	0.2–0.3 g	0.04–0.12 g	0.10 g
Pituitary gland	1–4 g	0.4–0.8 g	0.4–0.8 g
Skin and vessels, etc.	56–76 lb	12–16.6 lb	Not removed
Spinal cord	100–150 g	40 g	50 g
Spleen	1–3 lb	0.17–0.5 lb	0.2–0.7 lb
Stomach	16–25 lb	1–2 lb	1–4 lb
Suprarenal	11–25 g	1.5–5 g	3–5 g
Testes	0.5–2 lb	2–4 oz	3–5 oz
Thymus	0.3–1 lb	15–25 g	9–35 g
Thyroid	0.6–1.5 oz	2–9 g	4–10 g
Total	1000 lb	85–90 lb	215–225 lb

[a]1 lb = 454 g, 1 oz = 28.35 g

Ockerman (1975), Moulton and Lewis (1953), British Food Manufacturing Industries Research Association (1978), Romans *et al.* (1985), CSIRO (1977, 1978), Maurer (1951).

cold acetone. This solvent dehydrates and defats at the same time. It is, however, difficult to evaporate acetone from the finished product. If the dried gland contains too much fat, it may not be powdered without defatting. This may be accomplished with the solvents: gasoline (mixture of C_4 to C_{12} hydrocarbons), light petroleum (C_2H_6 and up), ethylene dichloride (C_4H_4Cl), benzene (C_6H_6), acetone (C_3H_6O), carbon tetrachloride (CCl_4) or ether ($C_4H_{10}O$). Carbon tetrachloride in the presence of water corrodes equipment. Ovarian and testes preparations are often not defatted because the active principles are fat soluble. After drying and defatting, many of the products are milled to a powder form and then tested for safety (safe in normal dosage and, if to be ingested, sterile and free from undesirable substances) and potency prior to sale. After defatting, the glands are finely ground in a ball mill (jar

containing pebble-like objects) or a mill that cuts the glands into pieces and then the gland particles are sifted (from 40 to 100 mesh, usually 60–80 mesh) to remove connective tissue. The particles may be used as they are, or the active principle may then be chemically solvent-extracted (e.g. with acetone (C_3H_6O) and alcohol (C_2H_6O) for insulin), concentrated and purified (often centrifugation and filtration). The gland products are tested for activity by the procedures described in the United States Pharmacopoeia Reference, the National Formulary Reference and International Standards. Thyroid extract is tested for iodine level, since this parallels the medical properties of the gland, and it is also biologically tested for its ability to increase basal metabolic rate. Epinephrine is tested in dogs for its blood pressure raising properties (hypertensive properties). Suprarenal and anterior pituitary extracts are tested in rats that have had their glands removed to see if the extract will keep them alive and, in some cases to see if it will re-establish normal growth. Since potency can vary with each batch of glands, they must often be blended after testing to obtain the desired potency. Many glands or their extracts may be dispensed as powders, capsules, tablets, injections or in a dilute liquid form.

ADRENAL (SUPRARENAL CAPSULES)

The cocked-hat-shaped adrenal (also called suprarenal) gland (two per animal) secretes at least 20 steroids; is light chocolate in colour and is located above and touching the kidney (the bovine adrenal is on one side near the pelvis). The adrenal gland is composed of two sections, an outer cortex and an inner medulla which secretes steroids that are essential for life maintenance.

Corticosteroids from the adrenal cortex regulate the body's utilization of nutrients such as water and nitrogen and the balance of minerals such as potassium and sodium. Lack of secretion causes the debilitating Addison's disease, which results in progressive anaemia, low blood pressure, loss of weight, dark skin pigmentation, diarrhoea, loss of strength and a depletion of sodium. Extracted adrenal cortical steroids (i.e. adrenocortical steroids) from cattle, hogs and sheep are used for treating deficiencies of the adrenal glands (including Addison's disease), as anti-neoplastic and anti-inflammatory agents and for treating shock.

Cortisone is one of the corticosteroids. It regulates fat and carbohydrate metabolism, utilization of minerals and water balance. It also improves muscle tone, reduces pain caused by arthritis, and is used for treatment of shock and asthma. The quantities of steroids in the adrenal cortex are normally too small to compete economically with the corticosteroids manufactured from plant sources. Many oral contraceptives contain two steroid sex hormones: an oestrogen and a progesterone, which are currently also produced synthetically from plants. A synthetic cortisone has also been manufactured and it may be administered intramuscularly, orally or topically.

The adrenal medulla (inner portion) of the adrenal (all species) secretes epinephrine (adrenaline) and norepinephrine (arterenol and noradrenalin), hormones which constrict blood vessels, increase blood pressure and increase heart action. Epinephrine from cattle, hogs (pigs) and sheep adrenal glands is used by surgeons to arrest haemorrhaging, shrink blood vessels, prolong the effects of local anaesthetics, stimulate heart action and overcome shock. Epinephrine is also used to stimulate

body utilization of food, reduce symptoms of hay fever, alleviate allergies of the nasal mucous membrane, control bronchial asthma spasms, treat whooping cough, and reduce inner-eye pressure during glaucoma treatment. It is also used to reduce peripheral flow of blood in the body, slow the pace of rapid heart beats and restore heart rhythm in cardiac arrest. Norepinephrine is also used to shrink blood vessels, reduce peripheral blood flow and slow the rate of rapid heartbeats. Both epinephrine (laevorotatory form) and norepinephrine (bitartate salt) can currently be produced synthetically. They have been produced in powder, tablet, and aqueous forms for administration intranasally by inhalation, orally and parenterally.

ARTERIES

Bovine carotid arteries (Rosenberg *et al.* 1966; DeFalco, 1970) up to 55 cm in length and 9–11 mm in diameter may be treated with an enzyme (to remove parenchymatous immunologically reactive proteins), subsequently tanned (makes collagen stronger and more non-reactive) and then sterilized for later implantation into man as a femoropopliteal or iliofemoral substitute.

Fresh bovine carotid arteries are washed and physically stripped of fat and connective tissue down to the adventitia. They are then treated with a 1% aqueous solution of commercial ficin with a trace of L-cysteine (to assure activation of the enzyme) and buffered with citrate to a pH of approximately 5. Digestion for 2.5 hours at 37°C is terminated by deactivating for 24 hours to absorb the protease with a 1% solution of sodium chloride (NaCl). The arteries are placed over a glass rod then tanned for 18 hours with 1.3% dialdehyde starch at a buffered pH of 8.8. The tanned arteries are then washed in distilled water. The product is then sterilized by immersion in 1% propylene oxide (C_3H_6O) in 50% ethanol (C_2H_6O) solution and stored in this solution until insertion.

BEZOARS

Bezoars are accretions (aggregations or lumps) found in the stomach or intestines of animals. They are divided into:

Phytobezoars —(contain vegetable matter and salts of calcium and phosphorus) and are found in the intestines of horses, goats, gazelles, llamas, vicunas, and a few other ruminants. They were formerly reported to be an antidote for poisons.

Pilobezoars — (contain hair and other keratinous material) and are found in the rumen and other parts of the alimentary tract and are of no commercial value.

Bezoars are also sometimes classified (Divakaran, 1973) as in Table 7.5.

BILE

(See also 'Gall bladder')

Bile is a complex mixture of conjugated bile acids, bile pigments, fatty acids, phospholipids, proteins, cholesterol and other minor components. Approximately

Table 7.5 — Classification of bezoars

Type	Common name	Scientific name	Description
Bezoar	Goat	*Capra aegragus*	In stomach or intestine
Oriental bezoars	Gazelle	*Gazella dorcas*	Sometimes contain elagic ($C_{14}H_6O_8$) and/or lithofellic
(benzoaric) acid			
Occidental bezoars	Llama Vicuna	*Achenia glama* *Achenia vicugna*	Calcium, phosphate
German bezoars	Chamois	*Rupicapra tragus*	Vegetable and animal fibres

70% of the bile solids of ruminants is cholic ($C_{24}H_{40}O_5$) and deoxycholic acid ($C_{24}H_{40}O_4$) which are used in the synthesis of corticosteroids. The 'Meti' steroids, prednisone and prednisolone may be prepared from bile acids. Progesterone ($C_{21}H_{30}O_2$) and hyodeoxycholic acid ($C_{24}H_{40}O_4$) may also be prepared from bile. Pork gall contains chenodeoxycholic acid ($C_{24}H_{40}O_4$) rather than cholic and deoxycholic acids and therefore is worth much less than ruminant gall, which is more similar to human gall. Dehydrocholic acid, the oxidized product of cholic acid, stimulates bile flow and is used in the treatment of indigestion, constipation and bile-tract disorders. It is also useful in some fat-digestion disorders.

Bile extract is used to increase the secretory activity of the liver. Cortisone ($C_{21}H_{28}O_5$), an adrenocortical steroid hormone with anti-inflammatory properties similar to ACTH, can also be extracted from pig bile (see also the Adrenal and Gall bladder sections in this chapter).

Chenodeoxycholic acid extracted from pig bile has been found to be effective in dissolving cholesterol ($C_{27}H_{46}O$) gallstones (probably because it suppresses synthesis of cholesterol), which account for approximately 80% of human gallstones. In the U.S. there are 750 000 new gallstone cases each year.

Raw gall (specific gravity 1.025 at 8.5% solids) is concentrated (by a factor of 12 by weight) to 75% stable solids (inspissated bile). If not concentrated, it must be chemically preserved or frozen to prevent bacterial degradation. Cholic acid can be converted to deoxycholic acid and this can be isolated, or the cholic and deoxycholic acids can be separated by their different solubilities in weak bases and then purified. Usual processing consists of heating (refluxed for 3 hours) the gall with sodium hydroxide (NaOH; 1.5 to 2.5 N) to remove amino acids followed by precipitation of cholic and deoxycholic acid. The alkaline solution is treated with mineral acid to obtain a pH of 7.5–8.5. Magnesium chloride ($MgCl_2$) is added to the hot 90°C (194°F) mixture and the magnesium salt of deoxycholic acid is precipitated. Acidification of the filtrate yields crude cholic acid which is purified by recrystallization from methanol (CH_4O).

Bile and iron bile salts can be purchased as desiccated or liquid extract preparations derived from cattle or hogs.

BLOOD

Blood proteins are approximately 10% of the total protein content of an animal and more details may be found on its usage in Chapter 9. Crude blood albumin is used mainly in animal feeds and sausage items (Table 7.6). Human usage is likely to

Table 7.6 — Blood composition

Red blood cells — separated from whole blood and spray-dried at low temperature

Composition			
Protein (%)		93	
Fat (%)		1.2	
Moisture (%)		4.5	
Ash (%)		2.3	
pH		7.7	
Solubility index		2.0	
Standard plate count (g)		Less than 10 000	
Salmonella		Negative	
Amino acids	%	Amino acids	%
Alanine	8.5	Leucine	13.1
Asparagic acid	11.4	Lysine	8.8
Arginine	4.1	Methionine	0.8
Cystine	0.7	Proline	3.2
Phenylalanine	6.9	Serine	4.2
Glycine	4.6	Threonine	3.4
Glutamic acid	8.4	Tyrosine	—
Histidine	7.1	Tryptophan	1.2
Isoleucine	0.6	Valine	9.5

Powdered beef plasma — separated from whole blood and spray dried

Protein (%)	75
PER	2.14
Water binding	10–12 times its weight
Emulsifying capacity	Good
Emulsion solubility	Good
Skin formulation	Increases
Texture	Increases 'snap' or 'bite'
Shrink	Reduces
Flavour	Retains sarcoplasmic protein flavour

American Protein Corporation (undated, a, b).

increase as world wide protein deficiency increases. It is used in industry as a sticking agent for insecticides. Blood can be separated into several fractions that have therapeutic properties. Sixty-three per cent of blood is liquid plasma, of which

approximately 3.5% is albumin and 4% globulin plus fibrinogen. Blood is collected in a clean receptacle — 3% salt may be added — and stored in a cool place. However, preserved blood may not be used for human consumption. Blood albumin is prepared from blood collected using a canula and with the addition of anticoagulants. The blood is centrifuged to separate the red and white corpuscles from the plasma. The blood albumin is then defibrinated, clarified and dried. Crystalline serum albumin or fraction V bovine serum albumin is produced from pure serum albumin and is used in research and clinical medicine. Bovine serum albumin (BSA) which is purified and despecified (deactivated) is used to help replenish blood or fluid loss in animals. Purified bovine albumin is used in testing for the Rh factor in humans, as a stabilizer for vaccines, in antibiotic sensitivity testing and as an ingredient in moisturizing creams and lotions.

Pork-blood fibrin extract is used as a source of amino acids, which are incorporated into parenteral (infused intravenous) solutions for nourishing some surgical patients. Hog-blood plasmin (enzyme) is used in heart-attack patients to digest fibrin in blood clots. Thrombin (enzyme) from beef blood promotes blood coagulation and is used in the treatment of wounds in inaccessible parts of the body, such as the brain, bones and gastrointestinal tract (ulcers). Thrombin is also used to hold skin grafts in place and to 'cement' gaps where tissue has been removed surgically. Fibrinolysin (enzyme) is combined with deoxyribonuclease (enzyme from the pancreas) to aid in the removal of dead tissue from certain vaginal infections. It is also a cleaning agent for clotted blood or infected wounds and can accelerate the healing of skin damage by ulcers or burns. Foetal pig plasma contains no antibodies; therefore, it is useful in the manufacture of vaccines and for culture media. Purified pale, straw-coloured, foetal calf serum obtained by centrifuging clotted blood is used as a nutrient for tissue culture, in medical research for vaccine production and in cancer research. Approximately 40% of the world's supply of foetal calf serum is produced in Australia and New Zealand. The foetal calf blood is collected via the umbilical cord, the jugular vein or direct heart cannulation. The blood should be chilled but not frozen. After it is centrifuged the serum may be frozen. Large volumes of blood are also utilized in cancer research since the quantity of albumin is reduced in the patients' blood, but gathers abundantly in cancer cells.

BONE CARTILAGE

Specifically processed xiphoid or xiphisternal cartilage from the breast-bone cartilage of young cattle is used by plastic surgeons to replace facial bone. Bone meal (e.g., 100-mesh powder, 60-mesh granular and 20-mesh products are popular) is also a nutritional source of calcium (averages 23%) and phosphorus (averages 12%) in the diet. Bone meal is also used as a filtering agent in water-purification systems. Steamed bone meal has had most of the protein and fat removed and contains approximately 32.5% calcium and 15.1% phosphorus. Marrow, marrow extract or red bone marrow, bone powder and bone ash (approximately 15.3–16.6% phosphorus) products are also available as human and animal dietary supplements. Red bone marrow is used to treat patients who have a low red blood cell count. It can be fed orally and is stable to heat and the action of the digestive juices.

BRAIN

(See also 'Nervous system' and 'Spinal cord' sections).
Brains (all species) are a source of cholesterol (15% of the dry weight of the brain) which is the raw material for the synthesis of vitamin D_3 (necessary for bone and teeth maintenance and to prevent rickets), which is a raw material for the synthesis of steroid pharmaceuticals, and is used as an emulsifier in cosmetics. Vitamin D_3 is also used to treat premature infants. A new technique for the degradation of cholesterol by bacteria has increased the yield of more valuable steroids. Wool grease and fish oil can also be a source of cholesterol.

The isolation of the hormone-releasing hormones from the hypothalamus that are responsible for release of hormones from the pituitary gland has resulted in a major breakthrough in hormone research. These hormones are also used in the manufacture of cholesterol. Thromboplastin, which can be isolated from brain tissue, is used as a blood coagulant in surgery. Cephalin (kephalin) prepared from brain or nervous tissue also assists in clotting of blood. Lecithin (phosphatidylcholine), from the same organs as well as from the liver, bile and blood, is useful as an emulsifier, as an antioxidant and in treating snake bites.

DUODENUM

Enterogastrone (hormone) is obtained from the duodenum (beginning of small intestine) of the hog and is useful in regulating the gastric secretions of the stomach and experimentally to accelerate the emptying time of the stomach.

Secretin (polypeptide hormone) is also obtained from the duodenum and is used to stimulate the pancreas gland to produce pancreatic juice. It is also used to test for disease of the pancreas.

An intrinsic factor is also isolated from the duodenum and it aids in the absorption of vitamin B_{12} by pernicious anaemia patients.

EGG-SHELL POWDER

Egg-shell powder (94% calcium carbonate) is used as a dietary supplement and finds a moderate amount of use in the poultry production area.

FEATHER

Feather fats contain cholesterol. For cholesterol information see the Brain and Nervous tissue sections of this chapter.

GALL BLADDER

(See also 'Bile' section).
The gall bladder bile (gall) yields such products as cholic acid (from sheep and ox, $C_{24}H_{40}O_5$), desoxycholic acid (from sheep and ox, $C_{24}H_{40}O_4$), chenodeoxycholic acid (from pig, $C_{24}H_{40}O_4$), dehydrocholic acid ($C_{24}H_{34}O_5$, used as a choleretic) and cortisone ($C_{21}H_{28}O_5$, anti-inflammatory) all which have found uses in the medical area. Both cattle and sheep galls are almost identical (10% solids which contain 60%

cholic acid and 6% desoxycholic acid), are good sources of steroid precursors and are used in the manufacture of steroid drugs. Desoxycholic acid sells for about twice as much as cholic acid. Chenodeoxycholic acid suppresses the synthesis of cholesterol ($C_{27}H_{46}O$) and is used to dissolve gallstones and thus avoid major surgery. Gallstones (usually cholesterol) usually from beef are believed by some cultures to have mystical aphrodisiac value and are consequently very expensive since they are found in extremely small quantities. Gallstones average only 0.038 g/head of bulls and cows slaughtered. Gallstones may be round, oval, triangular, polygonal or prism-shaped and are reddish-yellow to yellow–black. They should be handled very carefully since they are very brittle and tend to become dark when exposed to direct sunlight. Their shape can be deformed while they are moist, so they are dried (also they can mould) in a warm place on a wire gauze. After drying, they should be wrapped in tissue paper or cotton wool and then in paper. They are shipped in cardboard or wooden boxes. They are often used in these cultures as ornaments in necklaces and pendants. Ox-bile extract from liver bile (dehydrocholic acid) is used to treat indigestion, constipation and bile-tract disorders. Cortisone extract from bile is used to relieve pain by reducing inflammation in joints of people with arthritis. Cortisone can now also be produced synthetically and is administered intramuscularly, orally or topically.

Gall can be removed from the bladder by cutting and hand-draining or by using a gall extraction machine which works on the principle of crushing the bladders between a set of rollers and squeezing out the gall. There are two separate hoppers and different rollers for beef and mutton bladders. Gall yield is approximately 0.4 kg (0.9 lb) for beef animals heavier than 200 kg (441 lb) dressed weight and 0.3 kg (0.7 lb) for beef animals lighter than 200 kg dressed weight. There is very little demand for hog gall since its different chemical composition has little pharmaceutical use.

Liquid bile is frozen in a container, with each day's supply being added to the previous layer of frozen bile until the container is full. It is then shipped frozen to the pharmaceutical processor. In some cases 1.8 kg (4 lb) (approximately 1%) of solid caustic soda (NaOH) or 3.6 kg (8 lb) of a 50% solution is used without freezing or 907 g (2 lb) of technical grade chloroform ($CHCl_3$) is added to each 208 l (55 gallon) drum of bile. If chloroform is used, the product should be kept below 4°C (40°F). Formalin (37% CH_2O) is also sometimes added but it makes the product difficult to refine. In some countries, the gall (14–15% solids) is concentrated (difficult because it is highly hygroscopic) by heating to a solid content of 75% (85–97% reduction in volume and weight) prior to shipment. Solid content can be estimated by using a specially calibrated refractometer at 66°C (150°F). For example, 22° Baumé is equivalent to 67.2% solids and 28° Baumé equals 81.6% solids in gall. The concentration of gall is accomplished by cooking in an open vessel at a temperature of 115–120°C (239–248°F); 0.56–1.05 kg/cm^2 (8–15 psi) steam in steam jacket) to evaporate the moisture to a 25% level. Gall is available in the crude, paste, or powder forms.

HAIR

Wool fats are also a source of cholesterol. For cholesterol information see Brain and Nervous tissue sections of this chapter.

HEART

Heart valves from young to market weight pigs are preserved and treated (converted to a 'biological plastic') prior to surgical implantation into the human heart in place of a defective valve (often caused by rheumatic fever or birth defects). The pig heart-valve (xenograft) is often preferred over a mechanical valve which requires constant infusion of anticoagulant (blood thinning) drugs to prevent the blood from forming clots on the valve (causing sudden malfunction) or free floating thromboemboli (causing stroke or paralysis). If a problem develops with a hog valve, malfunction is usually not fatal because (as with a natural valve) early warning symptoms alert the patient in time for reoperation. During the last 13 years approximately 200 000 Hancock (trademark of Johnson and Johnson Cardiovascular) bioprosthetic heart-valves have been produced from porcine aortic heart-valve tissue (Myers, 1986). The production procedure is illustrated in Fig. 7.2 and summarized from a description by Myers and Sharp (1986). Hearts of the right size are located and packaged on ice in styrofoam containers and shipped via air freight to the Southern California processing facility within one day of slaughter. The hearts are inspected upon arrival and the aortic valve is excised from the porcine heart in cleanrooms under aseptic conditions. The valve is removed (harvested) using a series of five cuts placed in such a way that excess heart muscle is removed without damaging the aortic valve. When harvesting is completed, each valve is placed into a buffered saline solution and stored under refrigeration until fresh dissection can be accomplished. The objective of fresh dissection is to dissect the harvested valves by means of scissors and scalpels to a point where the valve can be properly sized and the septal shelf can be manipulated to provide maximum flow area during the fixation process.

There are three separate steps in fresh-dissecting a valve. The first step is scissor cleaning which removes the bulk of myocardium and adventitia. The valve can then be turned inside out for a full examination of its interior architecture. Many valves are rejected at this stage due to structural or coloration defects. The valve is returned to its natural position for the second step, which is blade cleaning. Each valve must be trimmed to a thickness of approximately 2 mm with careful attention paid to the annulus and the area directly behind the right cusp margin of attachment. The tissue is kept in cold saline solution until fixation. The elapsed time between receipt and fixation should be as short as possible, so planning heart receipts with production schedules is very critical. Once blade-cleaning is completed, both coronary arteries are tied off with suture and the valve is attached to a fixation valve-holder.

In fixation, the valve is transformed from fresh tissue into what is called a 'biological plastic' by means of immersion in a 0.2% solution of glutaraldehyde, which adds additional collagen crosslinks to existing ones, thereby strengthening as well as fixing shape into the tissue. It also acts as a bacteriostat by inhibiting the growth of microorganisms. The actual fixation process is accomplished by the use of a recirculating fluid-pressure system. The pressure head is adjusted to 82 mm Hg for high-pressure fixed valves and 1.5 mm Hg for low-pressure fixed valves.

Both Hancock Standard and Modified Orifice (MO) valves are fixed under high pressure, whereas Hancock II and HLP (Hancock low pressure) valves are fixed using low pressure. Both types of glutaraldehyde fixation provide excellent heart valves, but low-pressure fixation has some advantages, such as preserving the natural

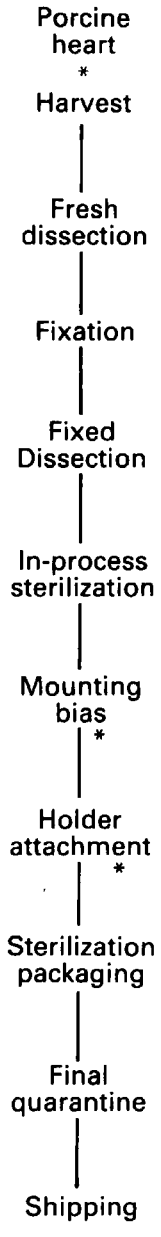


Fig. 7.2 — Porcine valve production process overview. *Quality control inspection points. From Meyers (1986).

spring-like structure (crimp) of collagen, which produces more flexible tissue. This increased flexibility translates into lower trans-valvular gradients, better overall flow characteristics, and increased durability.

After fixation, which takes a few days, the valves are transferred to individual containers of 0.2% glutaraldehyde and are then fixed-dissected.

Three critical tasks are performed at this step. The first is to fully inspect all surfaces of the valve for physical anomalies. This is accomplished first by the unaided eye and then, if necessary, by the use of a stereo-microscope. At this time a decision is made to section valves for MO production purposes if demand dictates. The second task is to trim, using scissors and a surgical scalpel, the aorta and annulus

areas until the annulus is thin enough to be accurately sized. Lastly, any adventitia that adheres to the outside of the aortic wall is carefully removed by forceps.

These valves are then mounted into appropriately sized frames (stents), again inside cleanrooms, under aseptic conditions. A valve of appropriate size is placed into the stent or conduit. The largest valve possible is used to ensure an optimum orifice and proper fit. The valve is checked and selected valves are ready for cleandown.

A scalpel is used to gently trim the myocardium from the endocardium so that only a very thin, smooth layer remains. This enables the tissue to be more flexible for stitching, less antigenic and less obstructive to blood flow. Irregular thickness in the annulus is also trimmed. The aortic wall tissue is not shaved or layered in any way. Once the valve is cleaned, it is stereo-microscope checked again, placed into the stent, and aligned properly. Alignment is important to ensure the natural central flow charcteristics of the valve.

The valve is now secured to the stent cloth or conduit with interrupted 4–0 stitches into the annulus. Stitches in stented valves are tied with square knots and pulmonary conduit stitches are tied with surgeon's flat knots. These stitches maintain the proper alignment of the valve throughout the mounting process. Several stitches similar to the annulus stitches are taken in each commissure to secure it to the stent post.

To finish the inflow of the valve, the endocardium is trimmed and folded under and the mitral leaflet area is cut flush with the stent. A continuous blanket stitch of 5–0 suture is used to attach this tissue to the stent. The valve is now checked again for proper assembly and possible leaflet damage from handling.

To finish the outflow of the stented valve, the aortic wall is trimmed even with the stent rails and posts. A strip of thin cloth cut on the bias is laid on the aortic wall and stitched down to the stent. This 'purse-string' type stitch of 5–0 suture is continuous and is called the first-step bias. Care must be taken not to stitch into cusps or commissures. To complete the second step, the bias strip is folded back over the first step and tucked between the tissue and stent. A whip stitch is used to secure the folded edge of the bias strip to the stent cloth. Each valve is inspected by quality control at this point.

The next step is suturing the completed valve to a holder, after which the valve is placed in glutaraldehyde in a sterilized package, passed through final quarantine and is then shipped to the surgeon for human implantation.

Pericardial tissue (membrane enclosing and attaching the heart in the thoracic cavity) from beef animals is also cleaned, glutaraldehyde-processed, and used to repair or replace the patient's own pericardial tissue after heart surgery. Use of this pericardial patch prevents the adhesion of the patient's myocardium to the sternum following surgery.

INTESTINES

Heparin (mucopolysaccharide) is one of the 'essential' pharmaceuticals extracted almost exclusively from pork and beef (high-yield) mucosa (inner) lining of the small intestine and lungs. The mucosa is often collected during the machining of casings and is either preserved in a raw state or processed into a dry powder prior to shipment to the heparin manufacturers. Heparin is also found in the liver. Heparin (phospha-

tide) is obtained by salt-solution extract and is precipitated from the saline solution with acetone. It is used to thin the blood (raise the viscosity), retard blood clotting (by inhibiting conversion of prothrombin to thrombin) and is used in the treatment of frostbite and burns. Heparin is also used to dissolve, prevent, or retard blood clotting during surgery and in organ transplants. It is administered intravenously or subcutaneously (also see Duodenum section in this chapter).

'Cat gut' used for internal surgical sutures is produced from the intestines of sheep, calves and other meat animals (twisted into one, two or three strands, cut, dried, polished and sterilized). Cat gut is sometimes impregnated with other chemicals, such as chromium trioxide, formaldehyde, iodine or silver, to alter its chemical or physical properties. Violin-string manufacturing is similar to the making of 'cat gut'. Tennis racket strings are also often made from the small intestine.

LIVER

Vitamin B_{12} (cyanocobalamin) has long been associated with the liver, and cooked liver has been used as a therapeutic treatment for pernicious anaemia for a number of years. Since vitamin B_{12} has been synthesized (from cultures of *Streptomyces griseus*), the liver source has become less critical and today many people are given injections of synthetic vitamin B_{12}. Liver extract, sometimes combined with folic acid, is still utilized and may be injected into the blood stream as a treatment for some types of anaemia. Liver injections have also been reported as a treatment for sprue (also called catarrhal dysentery — a long-term condition manifested by diarrhoea, weakness, emaciation and anaemia).

Desiccated liver (available in unfatted and defatted forms and granular and paste forms) containing added nutrients is often used as a nutritional supplement. Other products, such as liver-fraction paste, liver concentrate (available in powder or granular form) and liver protein fractions are available as dietary supplements.

Heparin can be extracted from the liver as well as the lungs and intestines.

Catalase (enzyme) from hog liver is used in food processing, cold sterilization of milk for making cheese and treatment of wrappers to retard deterioration of food. Catalase specifically catalyzes the decomposition of hydrogen peroxide.

Dehydrocholic acid from liver bile is used as a treatment of indigestion, constipation and bile-tract disorders occuring due to disease or surgery.

Liver meal made by drying ground liver should contain at least 27 mg of riboflavin per pound of product. Liver is also available as liver paste concentrate and desiccated liver, from either pork or beef (in powder, granular or freeze-dried form).

LUNGS

Heparin (mucopolysaccharide), an anticoagulant that prolongs the clotting time of blood is used to prevent blood clots and can be extracted from lungs, the liver or the intestine mucosa (usually pig and beef). It is being used in 'mini-doses' in the prevention of post-surgical pulmonary emboli by blocking coagulation of blood in the intact blood vessel. Heparin is also used to prevent gangrene in frostbite and as a burn treatment (see Intestines section in this chapter).

MINIATURE HOGS

Miniature hogs are often used as laboratory test animals because their pulmonary, cardiac, dental and prenatal brain development closely resembles that of the human. They are ideally suited for the study of human ageing and disease resistance.

NERVOUS SYSTEM

(See also 'Brain' and 'Spinal cord' sections.)
Cholesterol (steroid alcohol) can be extracted (15% dry weight of nerve tissue) from the spinal cord. The spinal cords are stripped from the back bone, freed from bone dust and splinters, chilled and then frozen. Cholesterol is a building block for male sex hormones and is used as a treatment when natural male characteristics do not occur. Cholesterol is a precursor of bile acids and is important in the synthesis of steroid hormones. These hormones are used to treat menopausal syndromes and prevent swelling of breasts when nursing does not take place after birth. Cholesterol is also a principal ingredient in the preparation of vitamin D which is produced by ultraviolet-ray treatment of cholesterol.

The white matter of bovine spinal cord is extracted for cholesterol with a solvent that will allow excess water to be distilled while extraction is taking place. The crude cholesterol extract is then boiled in an alcoholic sodium hydroxide solution and the ionic impurities are absorbed on an ion-exchange resin. Pure cholesterol is approximately 3% of the spinal cord's tissue weight. Cholesterol, when mixed with fat, will permit absorption of large quantities of water and is used in cold-creams and ointments.

OVARIES

Ovaries from pork carcasses are extracted for the hormones, progesterone ($C_{21}H_{30}O_2$) and oestrogens which may be used to treat some reproductive problems, such as functional uterine bleeding, abnormalities of the menstrual cycle and threatened abortion. Progesterone and oestrogen are also used as an oral contraceptive. Progesterone is used to prevent abortion and oestrogen is used in the treatment of menopausal syndromes. Oestrogen is also used in the treatment of breast and prostate cancer.

Pregnant sow ovaries (corpora lutea) are also the source of relaxin, a hormone often used during childbirth. Corpus luteum is available as a powder, tablets and capsules. When saving the ovaries, the fallopian tube is cut off even with the ovarian gland.

OYSTERSHELL

Granular or powdered oystershell is a by-product from the fishery industry and is utilized as a calcium dietary supplemental source.

PANCREAS

The pale, medium-size pancreas located near the stomach and liver at the beginning of the small intestine and in pork is sometimes known as pork sweetbread (not to be

confused with veal thymus gland). It has an internal and external section. The internal section secretes insulin, which regulates sugar metabolism, and the external secretions pass into the small intestine to aid in digestion of starch, protein and fat.

Insulin (a double-chain protein hormone, with the A chain containing 21 amino acids and the B chain containing 30 amino acids) is probably the best-known animal-gland by-product extract and is produced by specialized β cells in the pancreas called islets of Langerhans. Pancreas glands are spread out in trays in single layers and quick-frozen to assure maximum insulin yield, then stored frozen (can be for a considerable period of time) prior to extraction. Insulin can be extracted from the pancreas by grinding the hard-frozen glands into acetone (C_3H_6O) and alcohol (C_2H_6O), which prevents proteolytic destruction. Some procedures use an acidified alcoholic extraction followed by concentration of the extract at temperatures below 40°C (104°F) and removal of fat; then the crude insulin is salted out (insulin fraction floats to the top of the brine as a 'salt cake') and purified. The insulin is redissolved in a small quantity of alcohol, which is treated with ether ($C_4H_{10}O$). This causes the insulin to again separate as a solid. Additional steps with various solvents are used in the final purification until a clear, colourless solution of insulin is ready for testing. Insulin is also produced today by the enzymatic cleavage of a larger, relatively inactive precursor molecule called proinsulin. Insulin is purified by crystallization from a solution containing a small amount of zinc salt. Insulin is used in the treatment of diabetes (when the human pancreas fails to produce sufficient insulin to control the level of sugar in the blood) of which there are an estimated 4 million cases, and 420 000 000 doses of insulin are administered annually in the U.S. today. It requires the pancreas from 26 cattle (primary source) to produce insulin for one diabetic for one year. The primary amino acid sequence of insulin has been determined and it is now possible, but difficult and expensive, to synthesize insulin. Recently, insulin has been produced by bacteria into which human genetic material (DNA) that codes for insulin production has been introduced. This produces a cheaper, less antigenic, human-type insulin. Hog insulin is also especially important since its chemical structure most nearly resembles human insulin (only one amino acid difference, whereas beef has four or five amino acids different) and approximately 5% of diabetics are allergic to the beef form of insulin and can tolerate only insulin from hogs. Sheep pancreas is seldom used since it contains only a third of the concentration of insulin found in the bovine pancreas. Storage of insulin should be between 0 and 15°C (32 and 65°F) and it has a maximum frozen shelf life of one year.

Glucagon (polypeptide hormone) extracted from the alpha cells of the pancreas is used to elevate blood sugar and to treat insulin overdose or low blood sugar caused by alcoholism. It is also used in the treatment of some psychiatric disorders.

LPH (lipotropic hormone, lipase) from the pancreas is used as a digestive aid and in the absorption of fats and oils.

Other extracts from the pancreas include chymotrypsin, a milk-curdling proteolytic enzyme, and trypsin, another proteolytic enzyme used as a digestive aid to hydrolyse protein in the upper small intestine. Both trypsin and chymotrypsin are administered orally and by injection and used for their anti-inflammatory effect. Trypsin and chymotrypsin are used to remove dead tissue and speed healing after surgery or injury. Chymotrypsin has been used to facilitate cataract-extraction eye surgery. Trypsin is also used in large quantities in tanneries.

Proteolytic enzymes are used in cataract surgery to digest the zonular fibres that hold the lens in position. An incision is made in the corneosclera or outer wall of the eye, the posterior chamber is then irrigated with the enzyme solution, digestion is complete in 2–4 minutes and the enzyme is washed away. This permits the entire cataractous lens to be easily extracted from the eye.

Pancreatin is a mixture of pancreatic enzymes (e.g. amylase (starch), lipase (fat), trypsin (protein)) obtained from the hog (preferred because of the higher yield) or ox and is used to treat intestinal disorders and faulty digestion. Because of its high fat digestive capability it is used to treat cystic fibrosis (estimated 4 million cases in U.S.) and to peptonize milk. Pancreatin is also used in special foods (to assist in food utilization) and flavourings.

Pancrelipase (enzyme) from pork pancreas is used as a digestive aid in conditions of pancreatic insufficiency and to digest gelatin from spent X-ray film in the silver-recovery process. Approximately 60% of the total supply of pancreas glands in the U.S. is used for the production of insulin, and approximately 14% is used for the production of enzymes. In removing the pancreas it is important to obtain the entire tail of the gland since this contains the greatest concentration of insulin.

PARATHYROIDS

Four (the number is sometimes variable) small (wheat-grain size of 1 g or less) parathyroid glands are located near the base of the tongue close to, or embedded in, the thyroid; their secretions regulate the calcium content of the blood and the tone of the nervous system. The water-soluble parathyroid hormone (parathormone) from beef is used to treat human parathyroid deficiency, which results in conclusions, painful muscular spasms and paralysis, loss of calcium from bones, abnormal tooth development and cataracts. Its administration in powder or tablet form raises blood calcium, lowers blood phosphorus, increases ionized calcium in the blood and increases the amount of calcium and phosphorus excreted in the urine. Parathyroid hormone can now be synthesized and the human requirement can be partly met by this source.

PINEAL

The cone-shaped pineal or epiphysis cerebri is a reddish gland about a third the size (small pea) of the pituitary. It is located in the brain cavity behind and above the pituitary and is usually collected from beef and calf. Its secretions are extracted and sold in a tablet form. They regulate child growth, puberty, maturity, colour of skin and formation of freckles. The melatonin hormone extracted from the pineal gland is being evaluated for the treatment of schizophrenia, mental and physical development problems and mental retardation. In veterinary practice there is some evidence that an extract from this gland can significantly improve lambing rate.

PITUITARY

The greyish or pinkish yellow, hazelnut-size in cattle ($\frac{1}{8}$ of that size in hogs) two-part pituitary (hypophysis) gland is located at the base of the brain (easily collected from

pigs but more difficult from cattle) and is made up of an anterior and a posterior lobe, with separate functions. The pituitary is collected, quick-frozen, and maintained at −30°C until processed. The large (84% of total gland in cattle, 73% in hogs and 87% in sheep) front or anterior lobe produces:

(1) growth-promoting hormone (GH) (involved in giantism and dwarfism),
(2) thyroid-stimulating (thyrotropic) hormone (TSH),
(3) prolactin or mammary-stimulating (lactogenic) hormone,
(4) gonad-stimulating (gonadotrophic) hormone (function of ovaries and testicles), and
(5) adrenal-cortex-stimulating (adrenocorticotrophic) hormone (ACTH).

The smaller (16% of total gland in cattle, 27% in hogs and 13% in sheep) posterior lobe (more valuable) secretes compounds (pituitrin is a posterior pituitary secretion) that:

(1) control blood pressure and pulse rate,
(2) regulate involuntary muscles and contractile organs
(3) control the function of kidney, and
(4) govern energy metabolism.

The whole pituitary gland is also dried, defatted and powdered and used as a therapeutic agent. The pituitary first attracted attention because of its overdevelopment in the giant and its underdevelopment in the dwarf. There appears to be few body functions that this gland does not influence directly or indirectly. It is sometimes referred to as the master gland of the body.

Hormones extracted from pork pituitary glands are used to control growth and metabolism and to regulate the activity of other endocrine glands. ACTH is the most commercially extracted hormone (only ¾ g in 454 g of pituitary glands) from the pituitary and is used as a treatment for rheumatism, arthritis, eye inflammation, some skin disorders and multiple myeloma (a form of leukaemia). There are an estimated 7 500 000 patients in the U.S. with arthritis or rheumatism. A major function of ACTH is to stimulate the adrenal or suprarenal glands to produce a large number of steroid hormones. ACTH's most important medical use is to restore or evaluate the secretion of the adrenal gland and to treat arthritis, lupus erythematosus (inflammatory dermatitis), psoriasis, rhinitis (lesion of the nose), bronchial asthma (paraoxysmal dyspnoea), some eye inflammation, some respiratory problems, anaemia, infectious mononucleosis and leukaemia. Approximately 16 000 000 human doses of ACTH are produced (from 60 000 000 hogs) each year and the total quantity is produced from animal tissue. It is also used as a treatment for ketosis in animals.

ADH (vasopressin, antidiuretic hormone) from the posterior lobe regulates body water loss through the kidneys and is used to treat diabetes insipidus (excess water in urine) and to control blood pressure by constricting the blood vessels and stimulating passage of food through the intestinal tract, particularly after surgery. It is also used intramuscularly to test renal function. It is also useful in dispelling 'gas shadows'

when making abdominal X-rays. A pharmaceutical preparation of the same principle may be prepared synthetically.

Prolactin hormone (lactogen) is used to stimulate milk secretion from mammary glands and is being evaluated for use as an aid in treatment of breast cancer.

Oxytocin hormone from the posterior lobe is used to assist in childbirth and in obstetrical complications such as for inducing labour, increasing uterine muscle contractions, control of post-partum haemorrhage, increasing the release of milk by mammary glands, lowering blood pressure and as a wound-closer (often used by boxers). It is used in veterinary medicine to stimulate the letdown of milk in cows affected with agalactia. It can also be made synthetically.

Thyroid-stimulating hormone (TSH, thyrotropin) is obtained from beef anterior pituitary glands and is used to stimulate the thyroid glands to produce thyroid hormones and as a diagnostic tool for the function of the thyroid gland. It is especially useful in conjunction with radioactive iodine to locate thyroid cancer that has spread to other parts of the body. The patient drinks radioactive sodium iodide (atomic cocktail) which is incorporated into the thyroid and cancer cells at other locations. TSH is then injected for 3–7 days and the various locations are scanned to determine radioactivity.

Growth hormone (GH) has a direct effect on protein, carbohydrate and lipid metabolism and controls the rate of skeletal and visceral growth. It also has great potential for increasing animal production.

The pituitary gland is collected (care must be taken with pork since the posterior lobe is loosely attached and can be lost), trimmed, quick-frozen (−30°C (−22°F)) and held at this temperature until extracted. Pituitary has been marketed as pituitary body powder, tablets, anterior lobe, posterior lobe, liquid (particularly posterior extract) and as the specific extracts.

PROTEIN CONCENTRATE

Fish protein (e.g. blue whiting, sprat, or capelin) concentrate can also be used as a dietary supplement, particularly in areas of the world where people are protein deficient. Where fish offal is abundant it can be processed to yield 60–70% protein fish meal.

SEMINAL VESICLES

The seminal vesicles located on the bladder of male animals are a source of prostaglandins (hydroxy fatty acids). These are used routinely in many hospitals to induce parturition and in larger doses to induce abortion. The extract has also been used in treating gastric ulcers, bronchial asthma and in synchronization of oestrus in animals. It is also used in treating thrombosis and high blood pressure. It has been synthesized chemically.

SERUM

Foetal bovine serum is used extensively by cell culturists. It is used as a standard protein solution, to inactivate proteolytic enzymes, for virus propagation, as a media

for cells in the production of virus vaccines and in some microbiological media. It is collected from the foetus at the slaughterhouse by inserting a needle into the heart (closed system method) of the intact (dead) foetus immediately after removal with the offal from the slaughtered pregnant female. This is usually accomplished on a special section of the kill floor reserved just for this purpose. The blood is rapidly processed and the serum is quickly frozen. Care must be taken to minimize microbial contaminants and haemoglobin release that occurs when erythrocytes rupture. Also, exposure to light (yellow lights and bags are used) and air should be minimized. In some cases the serum is deactivated by heating for 30 minutes in a double boiler at 55±1°C (131±2°F).

The product is also filtered through three 0.1 μm pore-size filters, which eliminates mycoplasmas and reduces viral contaminants (HyClone, 1985). Types of sera products available include, defined foetal bovine, characterized foetal bovine, defined calf bovine (supplemented), defined equine (donor), adult bovine, porcine and bovine amnionic fluid (HyClone, 1985). Other supplies produce sterile pooled deactivated sheep serum, sterile deactivated sheep (one animal) serum and sterile pooled deactivated bovine serum (Divakaran, 1982).

SKIN

Pork skin is a source of gelatine (see Chapter 5) and is also an edible product (see Chapter 2). Collagen is approximately 33% of the animal body total organic matter content. The extracted collagen product can aid in stimulating blood clotting during surgery. Pork skin is similar to human skin and can be converted into dressing that can be used for burn or skin-ulcer patients. Pork skin is removed from the carcass, cut into strips or patches, shaved of hair, split to 0.2–0.5 mm (0.008–0.02 in) thickness, cleansed, sanitized and packaged (chill-stored or frozen). It is often used within 24 hours after removal from the carcass. It relieves pain, inhibits infections, prevents loss of body fluids, eases the flexing of joints and stretching of scar tissue. This dressing prepares the patient for permanent skin grafting by promoting the development of granulation tissue, which is necessary for skin grafting.

Gelatine produced from hog skin is used for coating pills and making capsules (see Chapter 5).

SPINAL CORD

Cholesterol can be obtained from the spinal cord (see brain and nervous system sections) for the synthesis of male sex hormones which are used when natural development does not occur. These hormones, often collected from beef and calf, are also used to treat menopausal syndromes and are used to prevent swelling of breast and milk production when a mother does not nurse a newborn. See also the Nervous system section in this chapter.

SPLEEN

The spleen is often collected from beef and pork carcasses for pharmaceutical use. The spleen (largest structure in lymphoid system) extract (splenin fluid) influences

capillary permeability, recovery from inflammation (redness and swelling) and blood clotting time. Spleen extract is also used to treat certain blood and lymph diseases. It is marketed as powder, tablets and capsules.

STOMACH

Hog stomach lining is the source of several proteins and enzymes used as digestive aids and antacids.

The pork stomach lining produces pepsin (enzyme) which is available in powder, granular, tablet or glycerol liquid forms and is used as a digestive aid to assist in the breakdown of protein into proteoses and peptones and to treat achylia gastrica (failure of stomach to produce acid and pepsin). Achylia gastrica is often associated with pernicious anaemia and stomach cancer in combination with achlorhydria, or lack of hydrochloric acid.

The hog's red or 'blushing' part of the stomach lining should be washed in cold water, spread out in thin layers and thoroughly chilled and then frozen until extracted or preserved in 1% sulphuric acid (H_2SO_4). The stomach is mixed with water and hydrochloric acid and digested at a little above body temperature. The solids are precipitated and the yellow liquid containing pepsin is purified by fractional precipitation. It is then dried at low temperature under vacuum. Extracted pepsin is in the form of pale yellow lustrous scales, granules or spongy masses, or a white or cream coloured powder. After processing and extraction, 26 g (1 oz) of pepsin will digest the boiled whites of 300 dozen eggs. Pepsin, from the hog stomach, is used when there is insufficient secretion by the patient's stomach to control the degradation of proteins into proteoses and peptones and is also used to clot milk in the manufacture of cheese and to modify certain protein foods, and is added to some chewing gums. Pepsin is also used to manufacture peptones, in the building of new protein units and in bacteriological medias.

The calf's digestive stomach tissue is often preserved by freezing or salting or simply by washing (in some cases not washed) and drying until rennin can be extracted. Rennet is an extract containing rennin (chymosin, milk-curdling enzyme) from a milk-fed calf's fourth stomach (abomasum and 5 cm (2 in) of the duodenal and 5 cm (2 in) of the third stomach or omasum). The calf's stomach may be saved by inflating with air and dried by hanging in a controlled heated room or more commonly by squeezing out the contents, splitting open, spreading out, salting and placing on a drying rack for 48 hours.

Rennin is used to help infants to digest milk and to curdle milk in the cheese-making process 28.5 g (1 oz) of rennin will coagulate 707 l (186 gallons) of milk in 10 minutes) and in the preparation of junket. Calf rennet, swine pepsin and microbial rennet from pure culture ferment, for example *Mucor pusillus*, individually or in combination with calf rennet and/or swine pepsin is used by the cheese maker to coagulate milk. Normally 56.6–84.9 g (2–4 oz) of rennin per 453.6 kg (1000 lbs) of milk is used and a curd will be formed in 30 minutes under normal conditions. Clotting time is affected by acidity, calcium level and temperature; therefore, combinations of coagulating materials are often useful. Rennets should be stored at less than 10°C (50°F) and at this temperature will lose approximately 1% of its activity per month.

The pyloric lining of the stomach is the source of an 'intrinsic factor' (glycoprotein), which is necessary for the utilization (absorption) of vitamin B_{12} or vitamin preparations to relieve or prevent pernicious anaemia. To isolate this factor all stomach processing must be done at a low temperature.

The stomach produces gastrin (polypeptide) a hormone that stimulates the production of gastric juices. The stomach also produces secretin that stimulates the activity of the pancreas to produce pancreatic juice and is used to test for diseases of the pancreas. The stomach and upper intestine produce cholecystokinin (CCK) which is a polypeptide hormone that promotes the emptying of the gall bladder. The duodenum produces enterogastrone (or anthelone E, obtained from hog's stomach), a hormone which mediates secretion and mobility of the stomach, and a hormone that stimulates the islet of Langerhans. Mucin (mucopolysaccharide or glycoprotein) from hog stomachs was formerly used to treat peptic and duodenal ulcers and to aid food passage (by lubrication) through the digestive tracts. Mucin is available in powder or granular form and is often considered as an adjunct to many digestive aid products.

TESTES

The enzyme hyaluronidase (invasin) extracted from the testes is used as a 'spreading factor' since it has the ability to hydrolyse mucopolysaccharides and thus to increase the rate of absorption, dispersion and distribution and consequently the effect of other drugs administered with it. It is usually obtained from bull (also sometimes calf and sheep) testes.

The hormone androgen is also produced in the testes and controls male characteristics.

THYMUS

The thymus (lymphoid organ) is located in the neck area of the chest cavity and in cattle the second lobe is located in the thoracic cavity. Thymus is divided into two parts: the cortex on the outside and the medulla within. The thymus (larger in young animals) has commercial food value (see Chapter 2) and is the source of extractable factors aiding the body to resist infection. It is also related to growth and calcification of bones and prevention of rickets. It is collected from all species and is marketed in powder, tablet and capsule form.

THYROID

The thyroid consists of two maroon-coloured masses or lobes on either side of the trachea and close to the larynx. In hogs, the two lobes are fused together. Its active substance is an iodine-containing hormone called thyroxin which is responsible for the speed of basal metabolism and used to treat hypothyroidism (3 300 000 people treated in the U.S. in 1976). The thyroid hormone used as a medication in hypothyroidism is derived from both pork and beef thyroids and the active ingredients can be prepared synthetically. It is taken orally usually in tablet form when the

thyroid gland secretes too little iodine-containing thyroid hormone, or after surgical removal of the thyroid gland.

Thyroxin deficiency causes 'cretinism' (in infants) or 'myxoedema' (in adults) resuting in physical deformity, defective mentality and loss of physical and mental vigour. Similar symptoms are found in patients with surgically removed thyroids or who have undergone extensive radioiodine therapy. Pork and beef thyroid powder or tablets have been used to treat this condition. A deficiency of iodine can cause goitre (enlarged thyroid). Over-secretion by the thyroid causes an increase in basal metabolism and the individual will become nervous and thin. Thyroid secretion is interrelated with the secretion of other glands.

Sheep thyroid has been used as a treatment for lack of growth and mental deficiency in children caused by lack of thyroid function.

Desiccated thyroid is used to supplement hypothyroid (thyroid deficiency) patients and this condition leads to slowing of both physical and mental processes.

Calcitonin (thyrocalcitonin), a polypeptide hormone containing 32 amino acids and also produced by the thyroid, is used to lower calcium and phosphate in blood and to regulate heartbeat. It is also useful to treat Paget's disease (bone disease with an incidence of approximately 2% of the population over 40). Calcitonin can also be obtained from the ultimobronchial gland of salmon; this is at least 20 times as potent as the porcine extract. Calcitonin is now also made synthetically.

Hog thyroglobulin (glycoprotein) is used as an oral supplement to underactive thyroid patients.

Egg production and hatchability is also reported to be improved by incorporating thyroid products into the chicken's feed.

Thyroid tablets are prepared from the hard-frozen gland by grinding, drying, defatting, milling, sifting, testing and blending for desired potency. The powder is then mixed with a suitable binding material, such as milk sugar, moistened, sifted, dried and pressed into tablets.

Thyroxin or tri-iodothyronine can also be prepared synthetically and is administered in tablet form. Approximately 41% (59% obtained from animals) of thyroid substance was obtained by the synthetic technique in 1976.

WOOL

Wool grease contains 15% cholesterol. For more information on cholesterol see the Brain and Nervous tissue sections of this chapter.

REFERENCES

American Protein Corporation (undated, a) *Powdered beef plasma.* Lytton, Iowa, American Protein Corporation.

American Protein Corporation (undated, b) *Beef red cells.* Lytton, Iowa, American Protein Corporation.

British Food Manufacturing Industries Research Association (1978) *Research report number* **292**. Leatherhead, England.

Committee on Textbooks of the American Meat Institute (1958) *By-Products of the*

meat packing industry. Institute of Meat Packing, University of Chicago, Chicago.

CSIRO (1977) Pharmaceuticals and other fine chemicals from animals. *Meat Industry Bulletin*. Oct. p. 36.

CSIRO (1978) Gall recovery. *Meat Research Newsletter*, Feb., 78/1, p. 1.

DeFalco, R. J. (1970) Immunological studies of untreated and chemically modified bovine carotid arteries. *J. Surg. Res.* **10** 95–100.

Divakaran, S. (1973) Cow bezoars and other animal stones. *Leather Science* **20** 17.

Divakaran, S. (1982) Animal blood processing and utilization *FAO Agriculture Services Bulletin* **32**. Rome. Food and Agriculture Organization of the United Nations.

HyClone (1985) *Advancing cell culture from an art to a science.* Logan, Utah, HyClone Laboratories.

Maurer, (1951) The value of saving glands. *National Provisioner*, Oct. 6, p. 137.

Missouri, Agricultural Experimental Station (1963) *Bulletin* **795** Columbia, Missouri Agricultural Experimental Station.

Moulton, C. R. and Lewis, W. L. (1953) *Meat through the microscope.* Institute of Meat Packing, University of Chicago, Chicago.

Myers, D. J. (1986) Written communication titled *Porcine value production process overview.* Anaheim, California, Johnson and Johnson, Cardiovascular.

Myers, D. J. and Sharp, C. (1986) Personal communication. Myers is manager of R & D Technical Services and Sharp is manager of Biological Production, Johnson and Johnson, Cardiovascular, Anaheim, California 92807.

National Live Stock and Meat Board (1975) *The good things we get from cattle besides beef.* National Live Stock and Meat Board, Chicago.

National Live Stock and Meat Board (1977) *Actually hog is man's best friend.* National Live Stock and Meat Board Chicago.

Okerman, H. W. (1975) Comparative anatomy of meat animals. In *Meat Hygiene.* Lea and Febiger, Philadelphia.

Romans, J. R., Jones, K. W., Costello, W. J., Carlson, C. W. and Ziegler P. T. (1985) *The meat we eat.* Interstate, Danville, Illinois.

Rosenberg, N., Martinez, A., Sawyer, P. N., Wesolowski, S. A., Postlethwait, R. W. and Dillon, M. L. (1966) Tanned collagen arterial prosthesis of bovine carotid origin in man. *Ann. Surg.* **164** 247–256.

University of Illinois and National Live Stock and Meat Board (1986) *By-product usage report.* National Live Stock and Meat Board, Chicago.

8

Sausage containers

INTRODUCTION

Ground and comminuted meat and sausage items often require food containers. These containers are usually natural casings, reconstituted collagen casings or artificial casings, frequently made from cellulose. A comparison of these sausage containers may be found in Table 8.1. In many cases, these food containers are obtained from the same or similar animal to that from which the meat was obtained and consist of animal casings which are made from various parts of the intestinal tract. They are often made from small and large intestines, weasand, urinary bladder, stomach and rectum. Terminology used in the sausage casing area is outlined in Table 8.2. Animal intestines are also used for the manufacture of surgical sutures and strings for musical instruments and tennis rackets. Intestinal tract that is not used for these purposes is converted into pet food, meat meal, tallow, or fertilizer, but certainly the most important economic use of these products is in the production of sausage casings. Animal casings, when removed from the carcass, are highly microbiologically contaminated. They are fragile and therefore cleaning must be carried out immediately after slaughter of the animal. The longer this process is delayed, the lower the quality of the casing that will be produced. Animal casings come in a wide variety of different shapes and sizes and the preference for a particular type of casing varies tremendously from country to country. The same part of the intestinal tract may also be used in different ways in different countries. A description of beef, hog (pig) and sheep casings as they are used in the U.S. may be found in Table 8.3. Many items will influence the value of an animal casing. Such things as the age of the animal, breed, fodder consumed and other factors related to the animals themselves or the conditions in which they were raised affect casings. Casings are often evaluated according to the following factors:

(1) Cleanliness — Casings should be clean and sound, free from stains, odour, fat particles, parasites, nodules, ulcers and other defects and without pinholes.

(2) Strength — Casings should be strong enough to withstand the pressure

exerted on them during filling, stuffing and processing. Only the submucosa part of the intestine has adequate tensile strength for this purpose.

(3) Length — The standard length for sheep and hog casings is 91.4 m (100 yards) per hank. Beef rounds are usually purchased in bundles of 18 m (59 ft). The number of pieces per hank or bundle often varies according to country of origin. The length of other animal intestinal containers also varies with the country of use and with the purpose to which the product is put. The average length for surgical catgut and tennis rackets and musical strings is 6 m (19.7 ft).

(4) Calibre — The calibre desired varies according to the country of use and type of sausage. Modern machinery used in the stuffing industry, however, requires a fairly uniform animal casing to have adequate machinability. Sheep casings are usually 14 mm (0.55 in) and over. The primary demand is for 20–24 mm (0.79–0.94 in) sheep casings. Small-calibre hog casings are substitutable for large-size sheep casings in some cases. The principal demand for hog casings is for the 35 mm (1.38 in) and over. Beef rounds are normally 35 mm (1.38 in) and over, and middles are 55 mm (2.16 in) and over and are the ones in highest demand. For specialized uses, sheep casings of 16 mm (0.63 in) and down are used.

(5) Curing — Casings are normally salted and cleaned. Fresh and fine salt should be used for curing. In a few cases, casings are dried. However, dried casings are not in large demand because they lose the necessary elasticity required in the stuffing operation. Intestines or ribbons of beef serosa for surgical catgut can be exported frozen; however, some countries import salted serosa for this purpose.

(6) Packaging — A number of types of packaging are presently used, including wooden and plastic containers, tins, and plastic bags protected by sacks. The trend, however, seems to be in favour of the plastic containers because of lower costs and sanitary requirements.

The intestinal tract and names of parts of a sheep, pig and cow may be found in Figs 8.1, 8.2 and 8.3 respectively. Also the casings manufactured from these intestinal tracts along with their size and capacity may be found in Tables 8.4, 8.5 and 8.6.

REMOVING THE VISCERA

The first step in removing the viscera is to open the brisket, which may be done with a knife and mallet and/or saw depending on the hardness of the bone, which will vary with age and species. Care must be taken not to cut the viscera, causing faecal

Table 8.1 — Comparison of casings

	Types		
	Natural	Collagen	Cellulose
Most expensive casing (cost per unit weight of product)	Most expensive	Less expensive	Least expensive
Refrigeration storage	Yes	Yes	No
Degree of tenderness	Most tender	Less tender	Peeled
Break during processing	Most likely	Less likely	Least likely
Casing preparation cost	Most expensive	None	None
Soaking and flushing before use	Yes	No	Sometime soaking
Ease of penetration	Most penetration	Less penetration	Least penetration
Cost of stuffing	Most	Less	Least
Best machinability	Least	Less	Best
Best product yield (per foot of casing)	Least	Less	Best
Smoke product penetration	Best	Very good	Good
Finished product uniformity	Less	Good	Good
Cost of casing removal	None	None	Most
Printability	None	Limited	Best
Old-world appearance	Best	Less	None
Ease of plant storage	Least storage	Less storage	Best storage
Shelf life without overwrap	3–4 days	6–8 days	7–10 days

Ockerman (1983).

material to contaminate the viscera or carcass. The next step is to make an incision and break the aitch bone. This is usually accomplished with a knife and mallet. Care should also be taken here not to cut the bung. The aitch bone incision is continued down the centre of the belly. The removal of the pizzle cords and bladder are accomplished next. Extreme care must be exercised in this operation to prevent cutting the viscera. The next step is cutting around the anal opening and dropping the bung into the carcass. Some plants use spreader hooks (pinning of sides) at this point to open the carcass. The viscera is then removed ('snatched') by cutting it away from the body and placing the viscera in viscera pans.

Separating the stomach, lungs, heart and livers from the intestine by cutting is accomplished next. Cutting or tearing the intestines must also be avoided at this step of the operation. If holes do occur, it is sometimes possible to wash and tie the casing and have it re-inspected.

After the casings have been separated from the attached organs, the casings are placed on a pulling table. The casing may be pulled with or without the large intestine

Table 8.2 — Animal casing terminology

Algien process is a method of manufacturing sausage that integrates the preparation of casing made from collagen and the filling of sausage.

Animal casings are prepared from the submucous coat (tela submucosa) of the intestines of cattle, sheep, goats, pigs, or horses. The other three coats of the intestine (serous coat (tunica serosa), muscular coat (tunica musularis) and mucous coat) are removed.

Beef bung is a casing prepared from the blind gut or caecum. The ileocaecal valve is 45.7–91.4 cm (18–36 in) from the blind end.

Black gut See Chitterling.

Bladder is a casing prepared from the urinary bladder of cattle or pigs.

Bundle is a set of beef casings, usually 18 m (59 ft) long.

Bung is part of the intestine which extends from the large intestine to the anal opening or crown.

Bung cap is a casing prepared from the blind end cut at the nipple hole.

Bung Skin is the outer section of the cap of the blind gut.

Cap a casing that is prepared from the blind end or caecum of sheep and has been salted and dried. Also may be prepared from hogs (see middle cap).

Cellulose casing is casing made from cotton. Cotton linters are first dissolved and subsequently regenerated into casings of various sizes. There are normally three types: small, large, and fibrous.

Chitterling or black gut is a casing prepared from a part of the large intestine of hogs.

Dry Pack is casing that was drained overnight before packing.

Dry ready-to-wet casing is a casing processed chemically.

Goat casing is a casing prepared from the small intestine of goats.

Hank is a set of sheep, goat or hog casings 91.4 m (100 yards) long.

Hog bung is a casing prepared from the end part (1.52–1.83 m (5–6 ft) of the large intestine, including the rectum and the anal ring (crown) of the hog.

Holes are openings of 3 mm (0.118 in) or more in diameter.

Large intestine is the portion of the intestine between the small intestine and the bung, often used for chitterlings.

Maws see stomach.

Middle cap is a casing prepared from the caecum or blind gut of hogs.

Middles is a casing prepared from the large intestine of cattle and pigs.

Prepared ready-to-use casing is an animal casing packed in a container with a special liquid.

Pre-tubed casing is an animal casing set in a spool.

Pulling is separating by hand the mesentery and fat from sheep, goat or pig intestine.

Reconstituted collagen casing is an edible casing prepared from reconstituted collagen, which is a protein (connective tissue) by-product obtained from the flesh-side of cattle hides. The collagen is purified and then extruded as dry tubes.

Rounds is a casing prepared mainly from the small intestine of cattle but which may also be prepared from sheep, goats or hogs.

Continued on next page

Table 8.2 — *continued*

Runners are prepared from the small intestine of cattle; one third of a sheep's intestine.
Running is separation by cutting the mesentery and fat from cattle intestine.
Sheep casing is a casing prepared from the small intestine of sheep.
Slime is the mucous lining of the intestine.
Slush pack is casing placed in containers without draining off the brine. Helps in preventing breakage on removal from the container.
Small casing is a casing prepared from the small intestine of hogs.
Splits are damage (bursting) to casings caused by the cleaning machines.
Stomach or maws is a casing prepared from the cleaned and sealed hog stomach.
Stump casing is a casing under 6 ft (1.83 m) in length.
Weasand is a casing prepared from the oesophagus of cattle. A No. 1 is over 610 mm (24 in) long, a No. 2 is 457 to 610 mm (18–24 in) long, and sausage weasand is less than 457 mm (18 in) long.
Windows are damage to casings caused by over-crushing. The windows are approximately 2.54 cm (1 in) apart and are half the thickness of the casing.

From International Trade Center (1973), Institute of Meat Packing (1958), Strange (personal communication).

Table 8.3 — Natural casings

Species	Name	Location	Appearance and comments	Sausage use	Average yield per animal
Beef	Round	Small intestine	Ring-like; tougher; easily handled; less breakage	Ring bologna; Polish sausage; ring liver sausage; mettwurst	27.4–41.1 m (90–135 ft) long
	Bung	Caecum	Curved; undulating	Capocolla; salami; large bologna	1.2–1,5 m (4–5 ft) long
	Bladder	Bladder	Oval or moulded	Minced speciality; mortadella	17.8–37.6 cm (7–14 in) wide
	Middles	Large intestine	Sewed; most expensive; adds uniformity	Bologna; salami	6.1–7.6 m (20–25 ft) long
	Weasand	Windpipe			45.7–66.0 cm (18–26 in) long

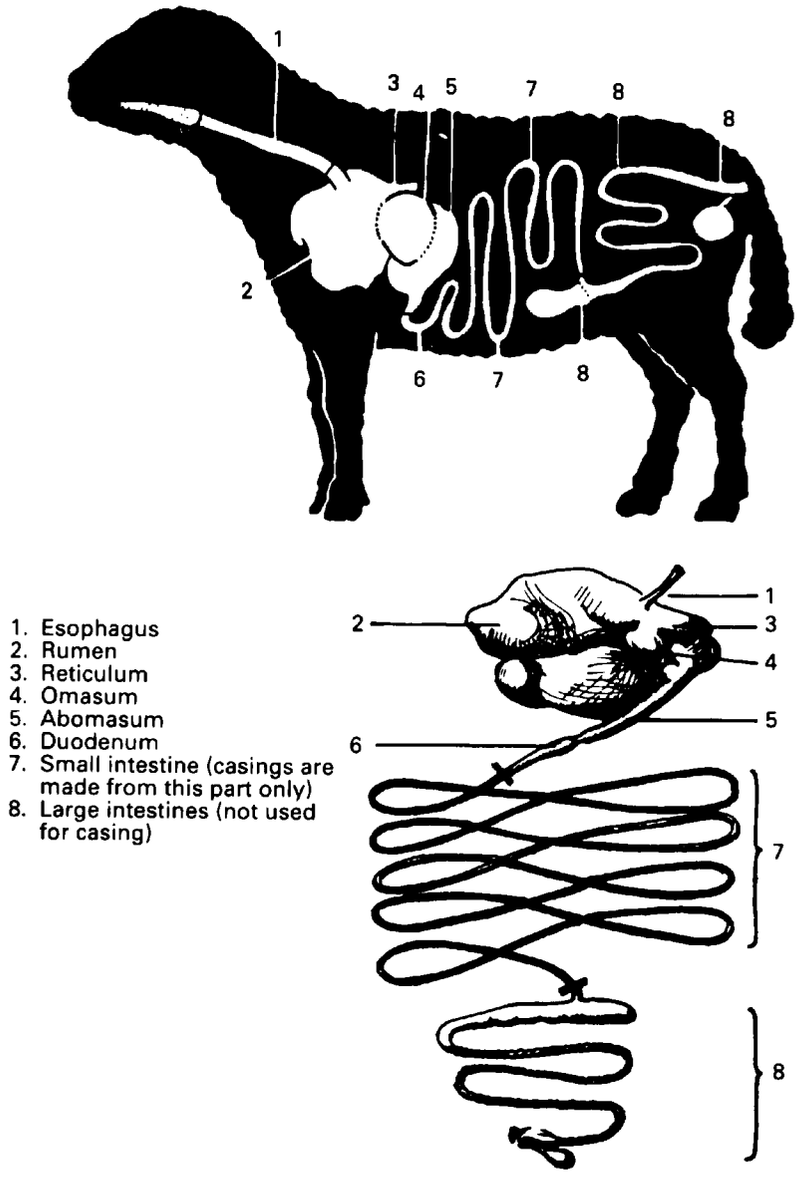


Fig. 8.1 — Diagrammatic representation of the intestinal tract of a sheep. From FAO of UN (1962).

attached. The ruffle (mesentery) fat may be removed by hand or with an air-operated knife. If the hand technique is used the operator will wear a cotton glove and should pull 60–70 casings per hour. An easy casing can be pulled in 25 seconds but a wormy casing may require in excess of 60 seconds. If an air-operated knife is used, 100–250 casings per hour may be pulled through the knife. Midwest and Northern U.S. casings can be pulled faster than Southern casings, which are less sturdy. The puller will start at the stomach and pull the casing away from the ruffle fat The casing is placed on a conveyor belt with one half of the casing on each side of the belt. A pulling tray (Fig. 8.4) is utilized with one side long enough to extend over the belt and the other side short enough to drop the casing on the opposite near side of the belt.

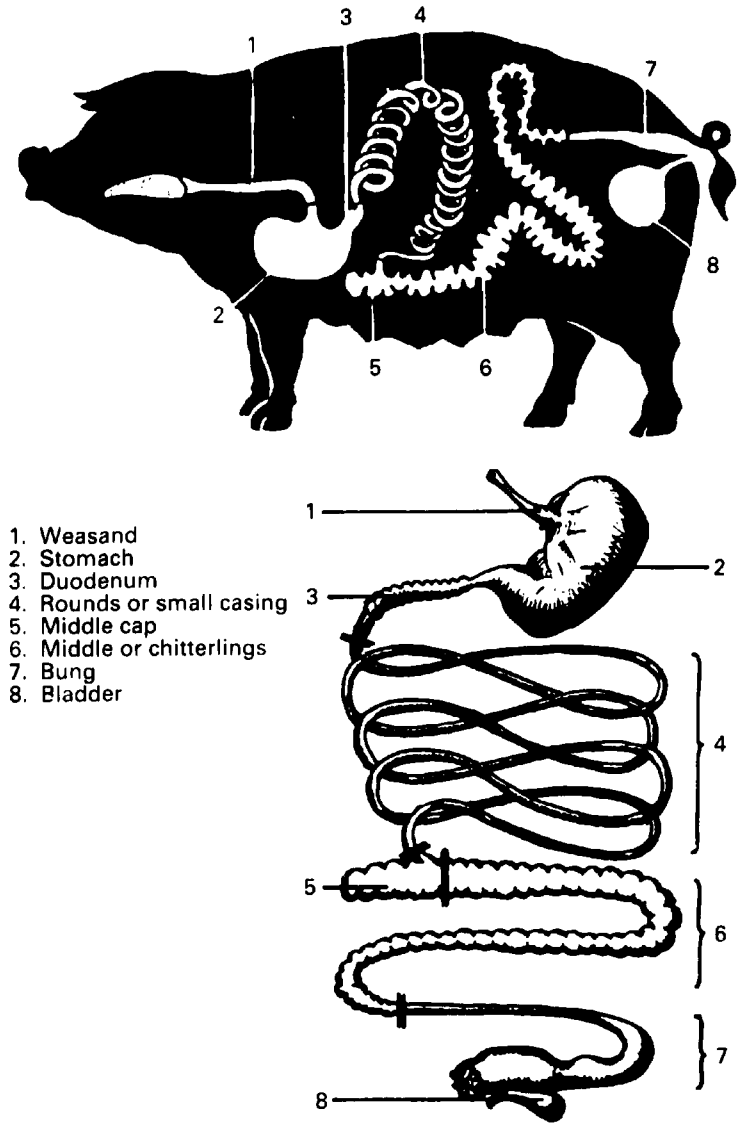


Fig. 8.2 — Diagrammatic representation of the intestinal tract of a pig. From FAO of UN (1962).

If the casing breaks, it can continue to be pulled since the casing will often become stronger and pulling can still be successful. If breakage continues, pulling from the large intestine end can be tried since this end is always stronger. The problem of pulling in this direction is that it is pulling against the grain and allows more objectionable blood capillaries or whiskers to remain on the casing. These, however, will cook off during the smoking operation. Each casing pulling station needs a 21–41°C (70–105°F) water spray to aid the casing to slide onto the respective sides of the trough. Often 15–25 cm (6–10 in) is removed from each end of the casing to aid in its travel through the subsequent stripping machines.

CASING EQUIPMENT

The pulling table, made of 12–14 gauge stainless steel with a centre drain, is used to separate the ruffle fat from the intestines. The table size is determined by the number

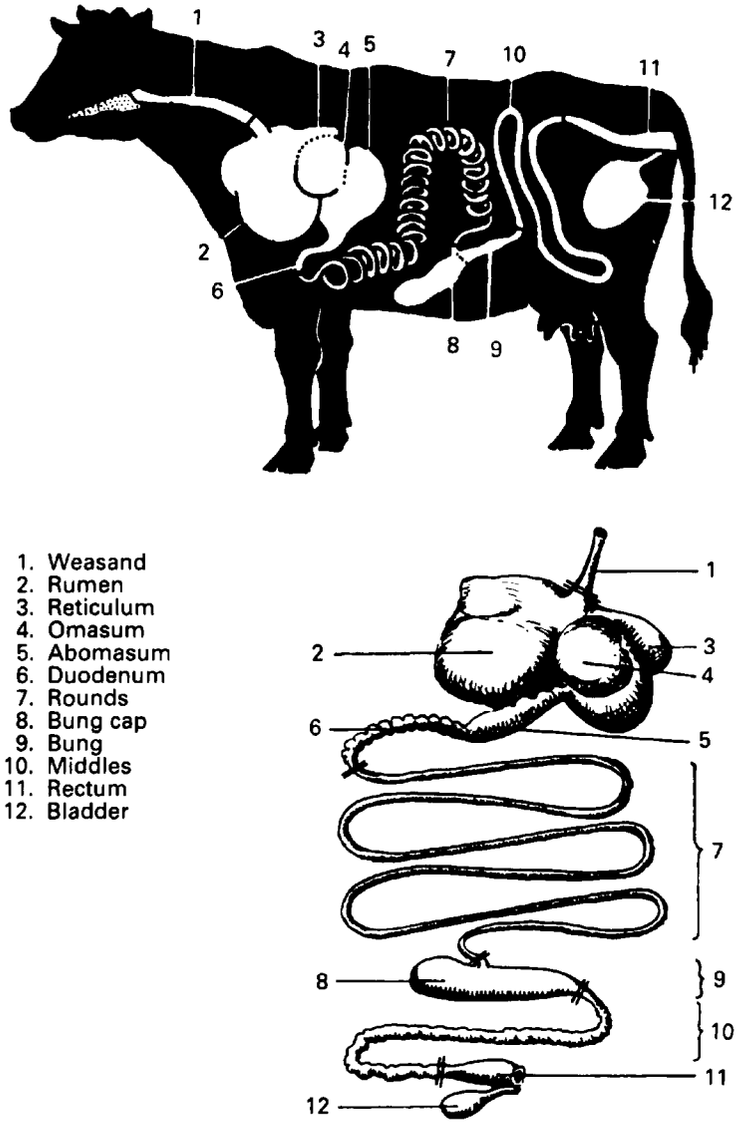


Fig. 8.3 — Diagrammatic representation of the intestinal tract of a cow. From FAO of UN (1962).

of pullers, whether or not the large intestine (black gut) is being saved, if a centre belt is used to remove casings and if chitterlings are being saved. Tables are often 2.7–3.6 m (9–12 ft) in length and up to 1.8 m (6 ft) in width.

The pulling tray, made of at least 14 gauge stainless steel, is long enough to extend from the edge of the pulling table to the far side of the conveyor trough. The tray also has a deflector shield on the short side to direct the casings to the opposite (near) side of the conveyor. This allows one half of each casing to be dropped over the conveyor belt and the two halves to drop into their individual depressions in the W-shaped trough. The conveyor belting runs in a channel at the centre of the W-shaped trough and often contains buttons or pins to hold the casing and to move them through the lower portion of a 12–16 gauge stainless steel W-shaped trough. Water sprays for the

Table 8.4 — Sheep casings

Grade	Approx. diameter (mm)[a]	Approx. capacity per hank (lb)[b]	Average hanks per tierce
Sheep casing (hanks of 914.4 m (100 yd) each)			
Narrow	16–18	33–36	600
Str. Medium	18–20	38–41	600
Medium Wide	20–22	47–52	550
Str. Wide	22–24	55–60	500
Special Wide	24–26	60–64	500
Extra Wide	Over 26	64–70	500
Shorts (0.91–1.82 m (3–6 ft) lengths)			
Str. Medium	18–20	34–36	500
Medium Wide	20–22	40–45	500
Str. Wide	22–24	45–50	500
Special Wide	Over 24	50–54	500
Sprinklers (pork sausage only)			
Wide	Over 22	53–57	650
Medium	18–22	40–45	650

[a] 1 mm=0.03937 in
[b] 1 lb=453.59 g
INSCA (undated), International Trade Center (1973).

trays should be at least 21°C (70°F). The conveyor pulls the casing over horizontal bars that help remove manure and then on to the manure stripper (Fig. 8.5)

The initial machine on the casing line is called a manure stripper and its purpose is to strip or sqeeze out the liquid and manure in the casing using two large rollers (e.g., 20–25 cm (8–10 in) in diameter, 183 cm (72 in) long) similar to a laundry wringer. These rollers may or may not be wrapped with canvas or burlap (often three times around the rollers) and they may also be rubber fluted. The manure strippers contains one and sometimes two, 1.9 cm ($\frac{3}{4}$ in) water lines to spray 41–43°C (105–110°F) water onto the rollers. The rollers are adjusted to have 2.4–3.2 mm ($\frac{3}{32}$ to $\frac{4}{32}$ in) clearance between them. The casings exit from the manure strippers and are conveyed through a 12–14 gauge stainless steel soaking tank (Fig. 8.7) which normally soaks the casing for 30 minutes at 38–42°C (100–108°F).

In a more primitive operation, the stripping may be done by hand. In this case the intestine is flattened and the casing is pulled between the fingers which forces out the residue. In some areas of the world fermentation is still used as a method of cleaning of casings. For fermentation the casings are soaked overnight in 21°C (70°F) water or until the mucous and muscular coating are loosened (see Fig. 8.6). Overfermentation, however, softens the casing. The casings are then stripped, often by hand, of the fermented material. They are then soaked in 38°C (100°F) water for approximately one hour and stripped again. The casings are then held for an additional hour and stripped a third time and then run through a cleaning machine (often a drum with

Table 8.5 — Hog casings

Hog casing (bundles of 914.4 m (100 yd) each, shorts are 0.91–1.82 m (3–6 ft) in length)

Grade	Approx. Diameter (mm)[a]	Approx. capacity per bundle (lb)[b]	Average bundles per tierce
Narrow	Below 32	90–100	335
Medium	32–35	105–115	325
English Medium	35–38	115–125	310
Wide	38–42	125–135	300
Special Wide	42–44	130–140	290
Extra Wide	Over 44	135–150	260
Medium Shorts	Below 35	80–90	305
Wide Shorts	Over 35	95–105	285

Hog bungs, regular

Grade (length in inches)[c]	Approx. diameter (in)[a]	Approx. capacity per piece (lb)[b]	Pieces per tierce
Sow (32 cut)	Over $2\frac{1}{4}$	$5\frac{1}{2}$	500
Export, Sow-in (32 cut)	Over $2\frac{1}{16}$	5	500
Export, Sow-out (32 cut)	$2\frac{1}{16}$–$2\frac{1}{4}$	$4\frac{1}{2}$	550
Large Prime (32 cut)	$1\frac{15}{16}$–$2\frac{1}{16}$	4	650
Medium Prime (32 cut)	$1\frac{13}{16}$–$1\frac{15}{16}$	$3\frac{1}{2}$	750
Broken Shorts (20–34 long)	Over $1\frac{15}{16}$	$3\frac{1}{2}$	800

Hog, middles

Grade	Per tierce
Cap off	Average 200 sets per tierce
Caps	Average 1200 pieces per tierce

Hog, stomach

Grade[b]	Per tierce
7 lb	300 pieces per tierce
5 lb	350 pieces per tierce

[a] 1 mm=0.03937 in
[b] 1 lb=453.59 g
[c] 1 in=2.54 cm
INSCA, (undated).

revolving scraper blades). The fermentation technique is not permitted under current U.S. federal inspection procedures.

The next machine is a crusher and, if one crusher is used, the time in the 38–42°C (100–108°F) soaking tank should be from 30 to 45 minutes, but if two crushers are used, this time can be reduced considerably. If casings are not soaked long enough,

Table 8.6 — Beef casing

Beef rounds (set of 100 ft each)

Grade	Average approx. diameter (mm)[a]	Average approx. capacity per set (lb)[b]	Average sets per tierce
Extra wide domestic	Over 44	85–95	125
Wide domestic	40–44	75–85	150
Medium domestic	Below 40	60–70	160
Extra wide export	Over 44	85–95	125
Wide export	40–44	75–85	150
Special wide export	37–40	70–80	165
Medium export	35–38	65–70	160
Narrow export	28–35	55–65	200

Beef bungs (minimum length 18 in[c])

Grade	Approx. diameter (in)[c]	Approx. capacity per piece (lb)[b]	Pieces per tierce
Extra wide export caps	Over 5	Over 12	800
Special wide export caps	$4\frac{1}{2}$–5	10–12	900
Regular export caps	4–$4\frac{1}{2}$	8–10	1000
Narrow export caps	$3\frac{1}{2}$–4	6–8	1200
Domestic caps	Over $4\frac{1}{2}$	9–11	850

Beef middles (set of 57 ft each[d])

Grade	Approx. diameter (in)[c]	Approx. capacity per set (lb)[b]	Average sets per tierce
Extra wide	Over $2\frac{1}{2}$	90–100	95
Special wide	$2\frac{1}{4}$–$2\frac{1}{2}$	80–90	110
Medium	2–$2\frac{1}{4}$	55–65	125
Narrow	Below 2	45–55	150

Beef middles, ready to use (sewed across one end)

Width (in)[c]	Length (in)[c]	Average approx. capacity per piece (lb)[b]	Average pieces per tierce
$1\frac{3}{4}$–2	18–20	$1\frac{3}{4}$	4000
2–$2\frac{1}{4}$	18–20	$2\frac{1}{4}$	3500
$2\frac{1}{4}$–$2\frac{1}{2}$	18–20	$2\frac{1}{2}$	3000
$2\frac{1}{2}$–$2\frac{3}{4}$	18–20	$2\frac{3}{4}$	2500
$2\frac{3}{4}$–3	18–20	3	2000

Continued next page

Table 8.6 — *continued*

Beef bladder

Grade	Kind	Approx. diameter (in)[c]	Approx. Capacity per piece (lb)[b]	Average pieces per tierce
Large	Salted	Over 7 Inflated	11–14	1000
Medium	Salted	6–7 Inflated	7–11	1400
Small	Salted	5½–6 Inflated	5–7	2400
Small	Dried	8–10 Deflated	5–7	2000

Beef middles, sewed

Kind	Width (in)[c]	Length (in)[c]	Approx. stuffing capacity (lb)[b]	Pieces per tierce
Single wall	2½–3	18–20	4–4½	2800
Single wall	3–3½	18–20	5¾–6¼	2700
Single wall	3½–4	18–20	6¼–6¾	2500
Single wall	4–4½	18–20	7–7½	2500

[a] 1 mm=0.03937 inches
[b] 1 lb=453.59 g
[c] 1 in=2.54 cm
[d] 1 ft=30.48 cm
INSCA (undated).

they will be reddish-pink in colour. The casings are then conveyed to the first crusher or stripper crusher (Figs 8.8, 8.9 and 8.10).

The crusher is designed to break the inner mucosa membrane (Fig. 8.6) and separate it from the casing. This machine normally contains two adjustable rollers on eccentric bearings. The first feeder (hold-down) roller is rubber fluted and is designed to feed the exit roller. These rollers have to be properly adjusted when they are cold. They are run at a water temperature of 41–42°C (105–108°F). This will soften and expand the rollers. A variation of 1°C (2°F) in water temperature will adversely affect the adjustment and, consequently, the operation of the machine. The crushing fluted roller is of soft stainless steel and balanced on both ends. It rotates three times as fast as the feed roller or the drum roller and is the most important roller used to clean the casing. The next roller in the crusher is called the drum roller. It is a non-adjustable, solid rubber roller against which the feed roller and crusher roller are adjusted. It travels at the same revolutions per minute as the feed roller. If two crushers are used, they will be separated by a short conveyer and will travel at the same revolutions per minute or the first one will be slightly faster than the second. Mucosa (Strange, 1986) yield should be 613 g (1.35 lb) hog casing. Cold roller settings for the stripper crusher might be as in Table 8.7.

After exiting the crusher(s), these casings will be conveyed to another 41–42°C (105–108°F), 12–14 gauge stainless steel soak tank and then to the mucosa stripper (Figs. 8.11, 8.12, and 8.13).

The mucosa stripper is identical to the manure stripper and runs at the same

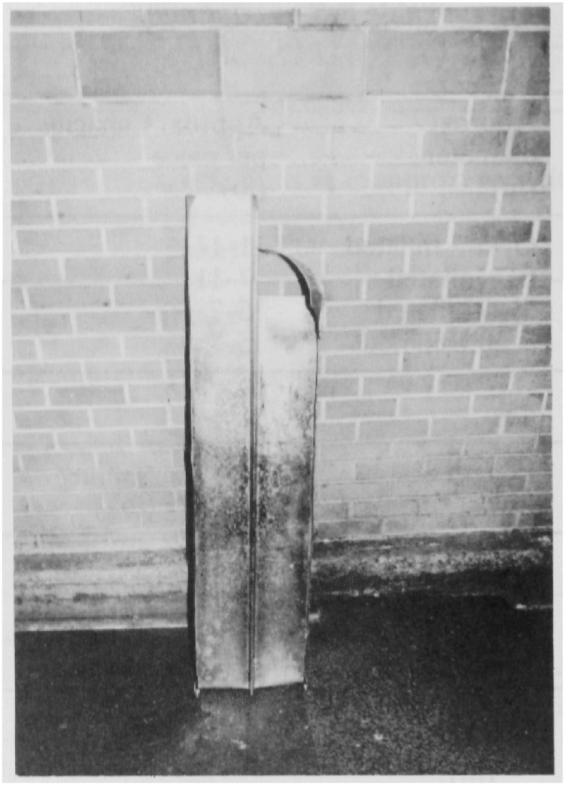


Fig. 8.4 — Casing pulling tray. From: R. D. Strange (personal communication).

speed as the last crusher. The rollers on the mucosa stripper may also be wrapped with burlap, but these become unsanitary very quickly and must be changed more often than on the manure stripper. Water-supply spray and water temperature is the same as used in the manure stripper 41–42°C (105–108°F). As the casings exit from the mucosa stripper, they are placed on hooks and are then hand-fed into the final finishing machine (Figs 8.14, 8.15 and 8.16).

The finisher's purpose is to remove all strings remaining on the casing and also to remove any remaining mucosa. The finishing machine has several types and sizes of rollers, such as a rubber fluted, smooth stainless steel and smaller rubber fluted, to pull casings through the machine. Normally there are four rollers adjusted as in Table 8.8.

The scraping rollers, at the entrance of the finisher, need 41–42°C (105–108°F) water and the pull-through rollers, at the exit side of the machine, need 10–16°C (50–60°F) or colder water. The finishing machine requires an operator continuously to strip 30–46 cm (12–18 in) by hand, to hand-feed the machine and also to monitor its operation.

STUFFING AND PACKING OF CASINGS

After the casings exit the finisher (Fig. 8.17) they are soaked in cold (10–16°C (50–60°F) or ice water) water or a salt brine tank (large enough to hold 2–3 hours production of casings) to remove excess blood. The colder the water, the easier it is

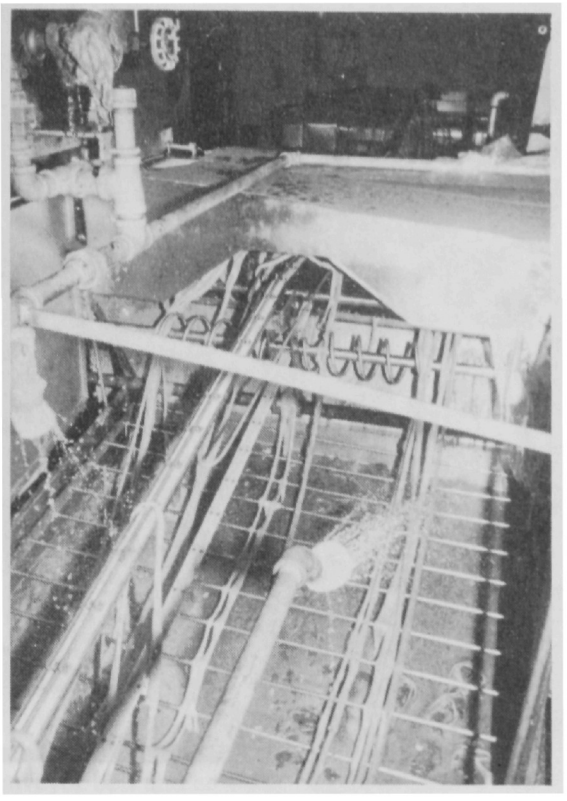
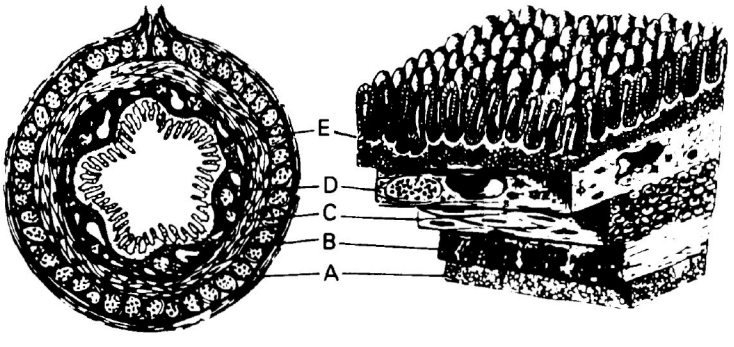


Fig. 8.5 — Casing conveyor belt, spray and entrance to manure stripper. From R. D. Strange (personal communication).



A. Serous coat (Tunica serosa)
B. Muscular coat (Tunica muscularis) Stratum longitudinale
C. Muscular coat (Tunica muscularis) Stratum circulare
D. Submucous coat (Tela submucosa)
E. Mucous coat

Fig. 8.6 — Diagrammatic cross-section of the intestines. Right-hand diagram emphasizes different layers forming the complete intestinal wall. From FAO of the UN (1962).

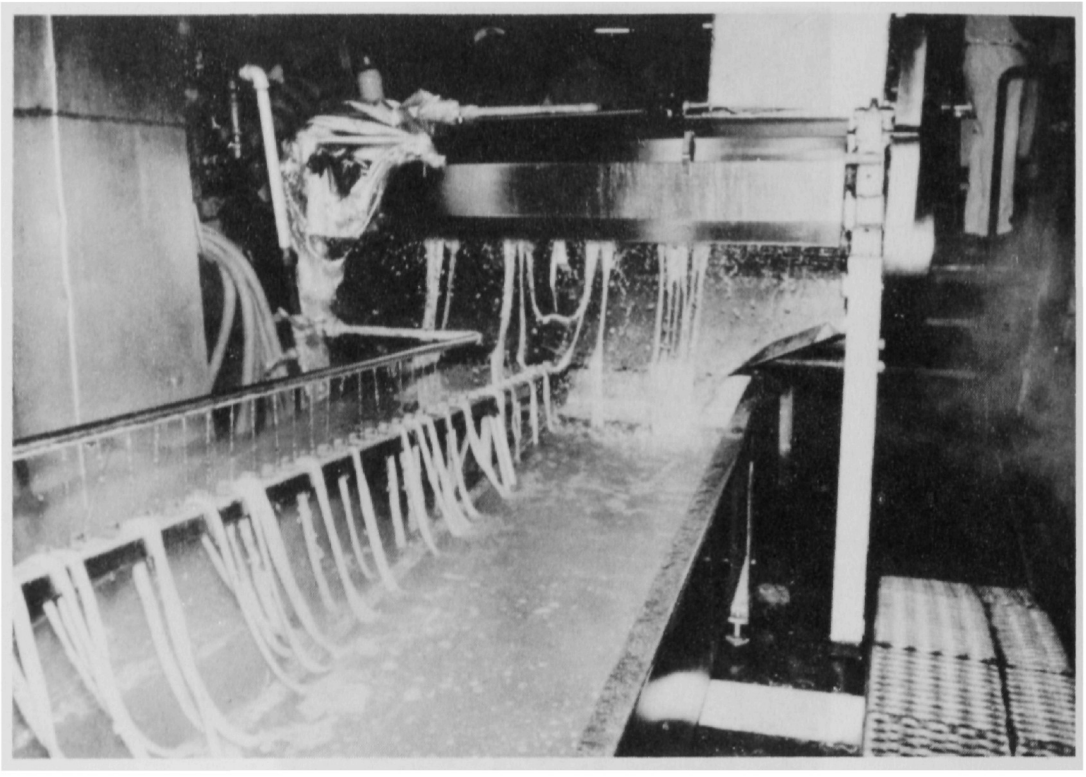


Fig. 8.7 — Exit end of manure stripper and casing conveyer. From R. D. Strange (personal communication).

to remove the blood. Salt in the water also improves the way the casings strip out of the tank, but since the tank usually uses running water, salt is often not used since it would have to be recharged rather frequently. A soak time of 45 minutes to 1 hour is required in a 10–16°C (50–60°F), 80–90% brine. Gentle stirring is desirable and the tank should be allowed to overflow the bloody water after 30–45 minutes of soaking. Often an overnight soak at −2.2 to −1.1°C (28–30°F) is used at this point.

As casings accumulate in the tank they are gathered into hanks, tied with twine and taken to the salting or packing room. A hank may contain from 20 to 50 pieces of casings (not necessarily full casings). The casings may be salted immediately or placed in buggies for transfer, or into stainless steel tubes for gravity feeding to the salting area.

Casings may be salted (NaCl, medium fine) by hand or with a machine. If hand salting is used, a hank of casings is removed and the casings stripped using a zigzag motion as they exit the soaking tank onto the salting table. Extra attention should be given to salting the portion where the string is located. Each bundle is tied in the centre and it may go directly to the packing barrel or to a drain area for overnight or a centrifugal extractor for 5 minutes if dry packing is used. After curing the bundles are shaken to remove some of the medium-fine salt (NaCl), and they are thoroughly rubbed with fine salt until they absorb 40% salt. A tamper may be used in dry packing if it is desirable to get more casings into the container.

If a salting machine (Figure 8.18) is used, less labour and salt are required. When

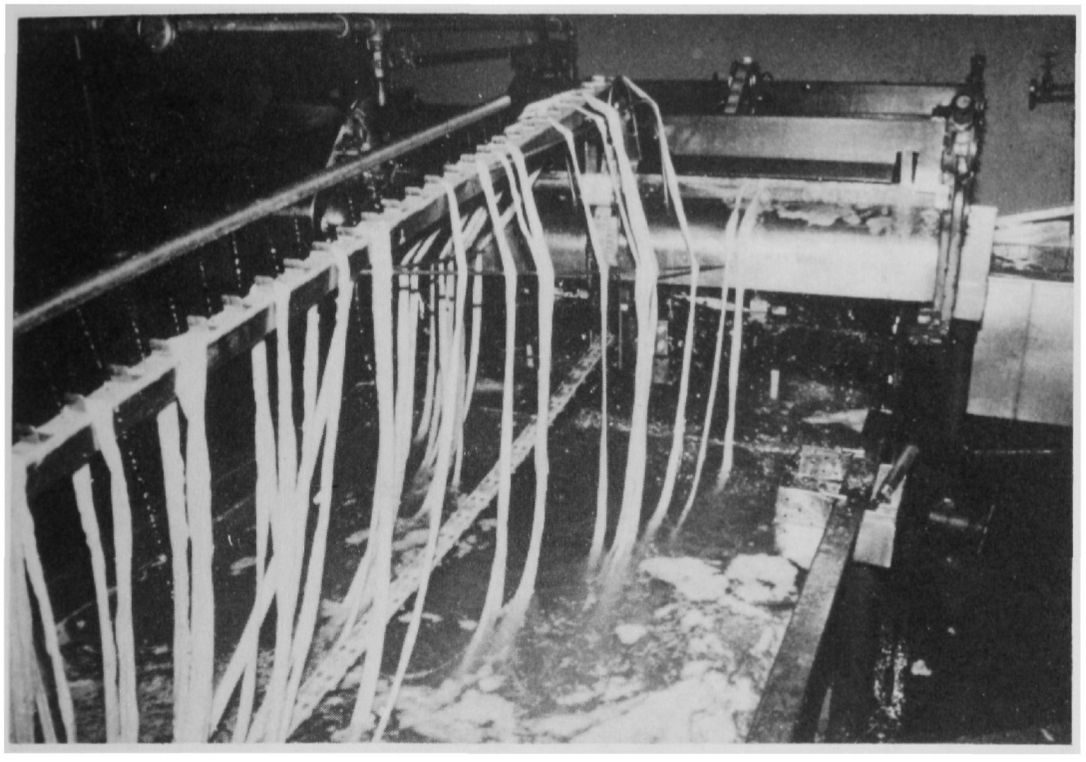


Fig. 8.8 — Casing conveyor belt and entrance to first crusher. From R. D. Strange (personal communication).

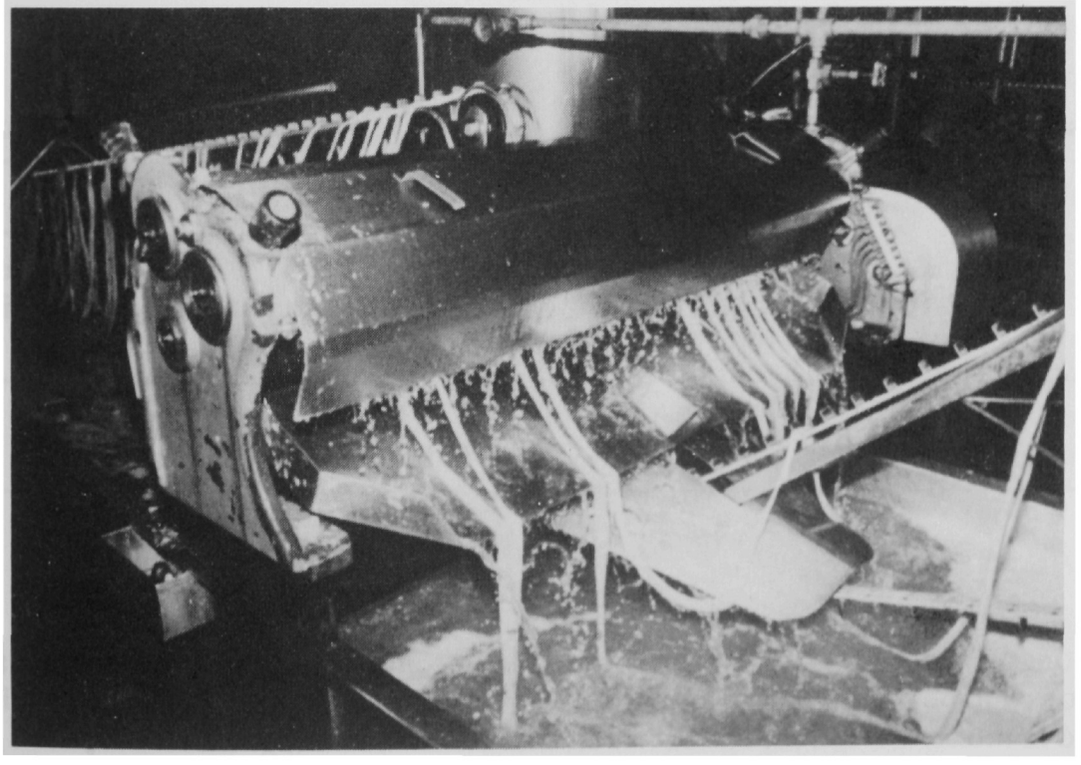


Fig. 8.9 — Exit end of first crusher and casing conveyor belt. From R. D. Strange (personal communication).

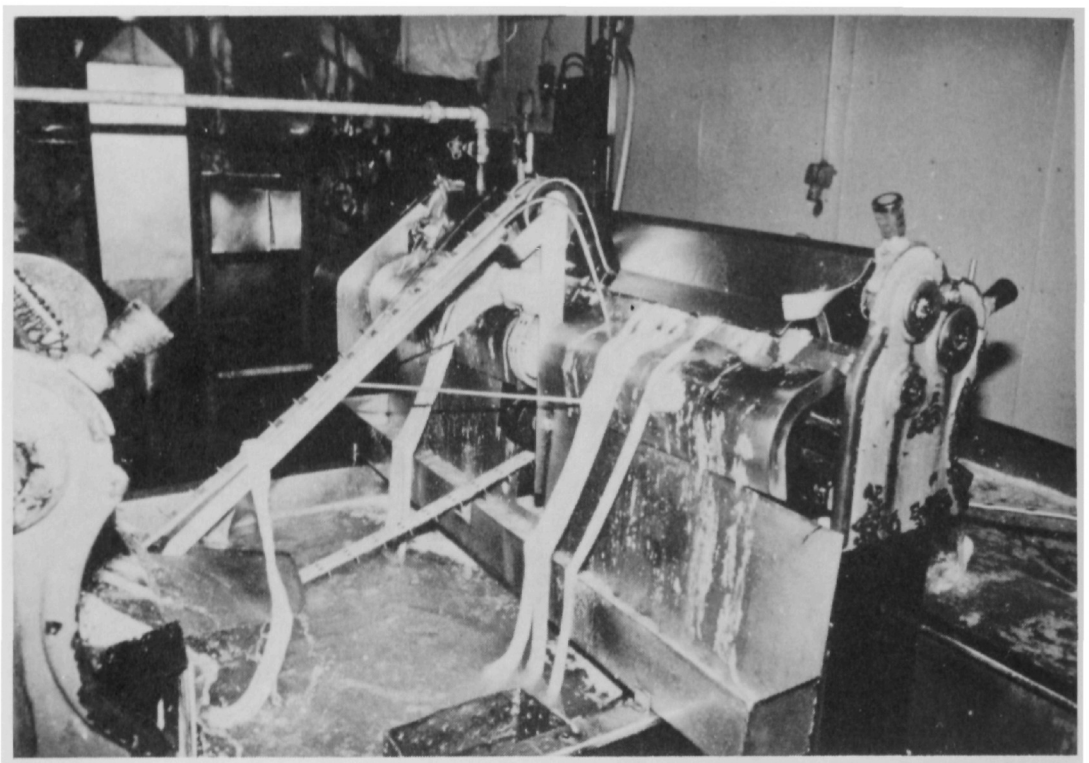


Fig. 8.10 — Casing conveyor belt and entrance to second crusher. From R. D. Strange (personal communication).

Table 8.7 — Cold roller settings for the stripper crusher in inches (1 in=25.4 mm)

Roller	One stripper used	Two strippers used	
		First stripper removes 75% of mucosa	Second stripper removes remaining mucosa
Feed roller	0.012–0.014	0.014–0.016	0.014–0.016
Crusher roller	0.008–0.010	0.010–0.012	0.008–0.010

salting by machine, the casing is pulled over a comb at the end of a salt table and allowed to be pulled from the soak tank through the salt on the table. The bundle is tied in the centre and the casing handled as with hand salting.

If casings are packed in a slush pack the bundles will go directly to the container after salting. When full the container will have 10–15% salt-water brine. These casings will not tangle as badly as dry pack casings but will be darker in colour

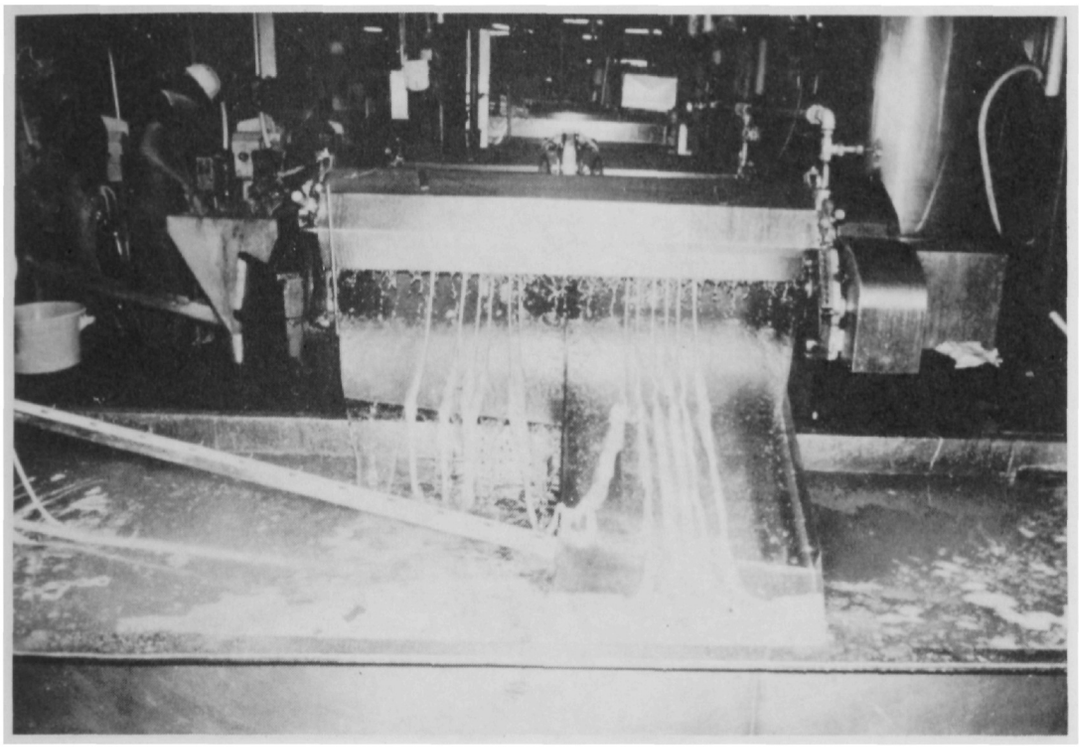


Fig. 8.11 — Exit end of second crusher and conveyor belt with spreaders. From R. D. Strange (personal communication).

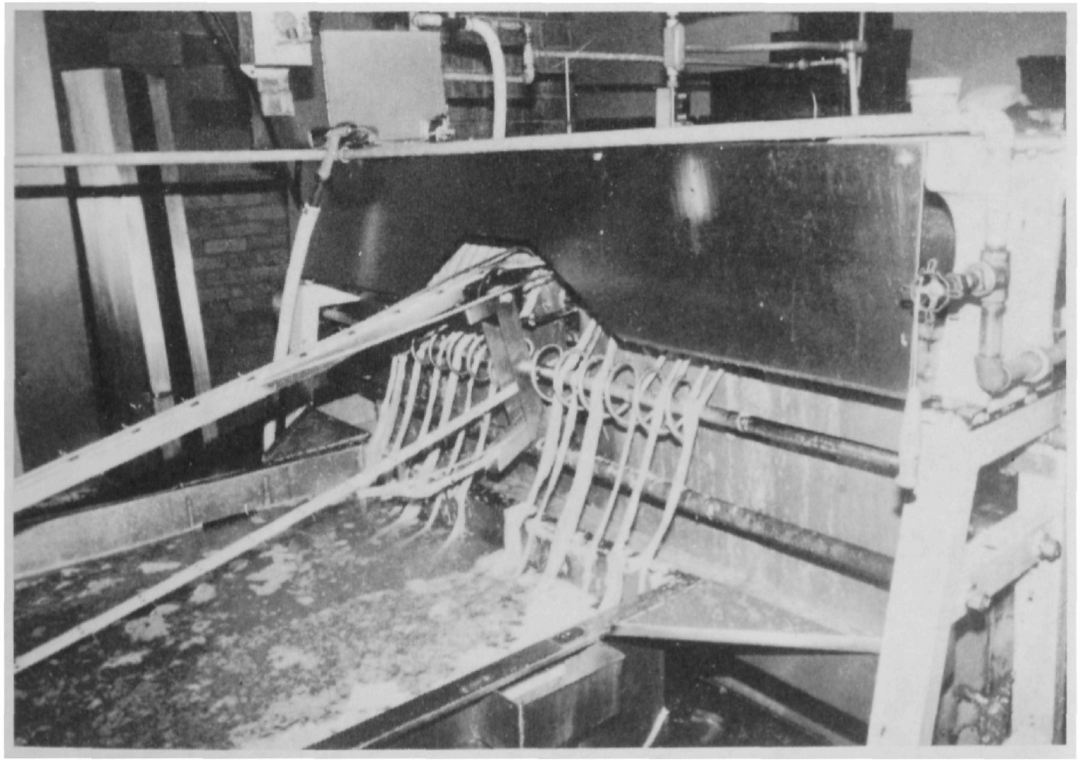


Fig. 8.12 — Casing conveyor belt and entrance to mucosa stripper. From R. D. Strange (personal communication).

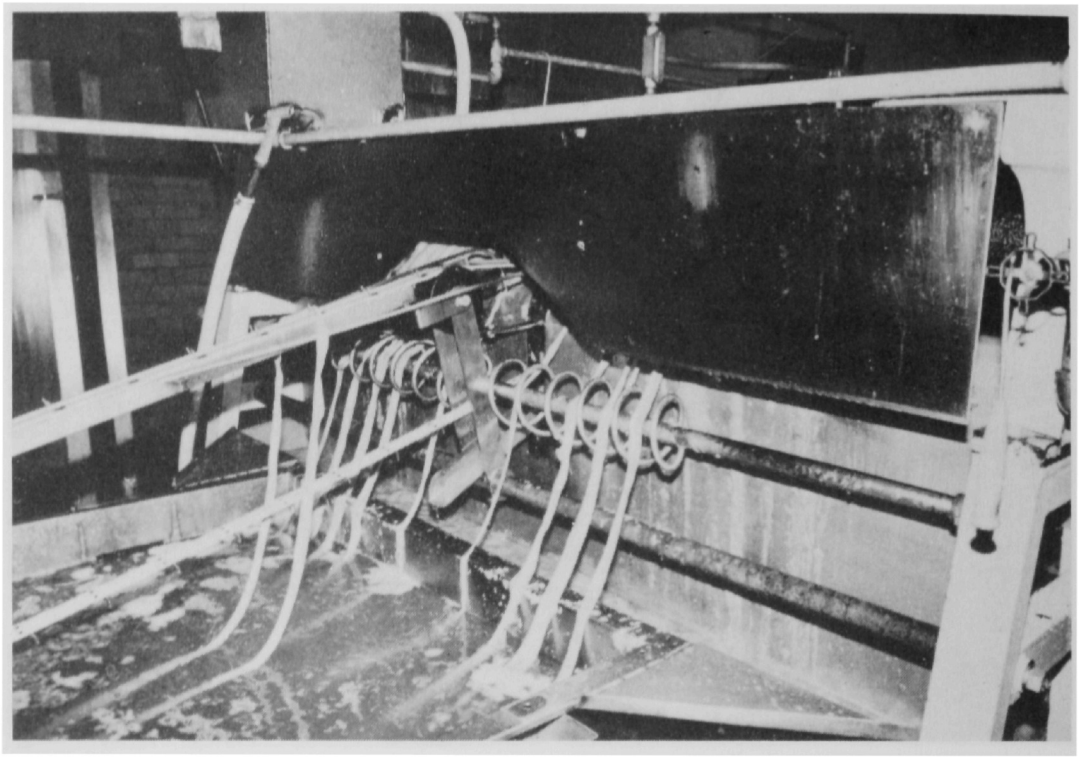


Fig. 8.13 — Spreader for mucosa stripper. From R. D. Strange (personal communication).

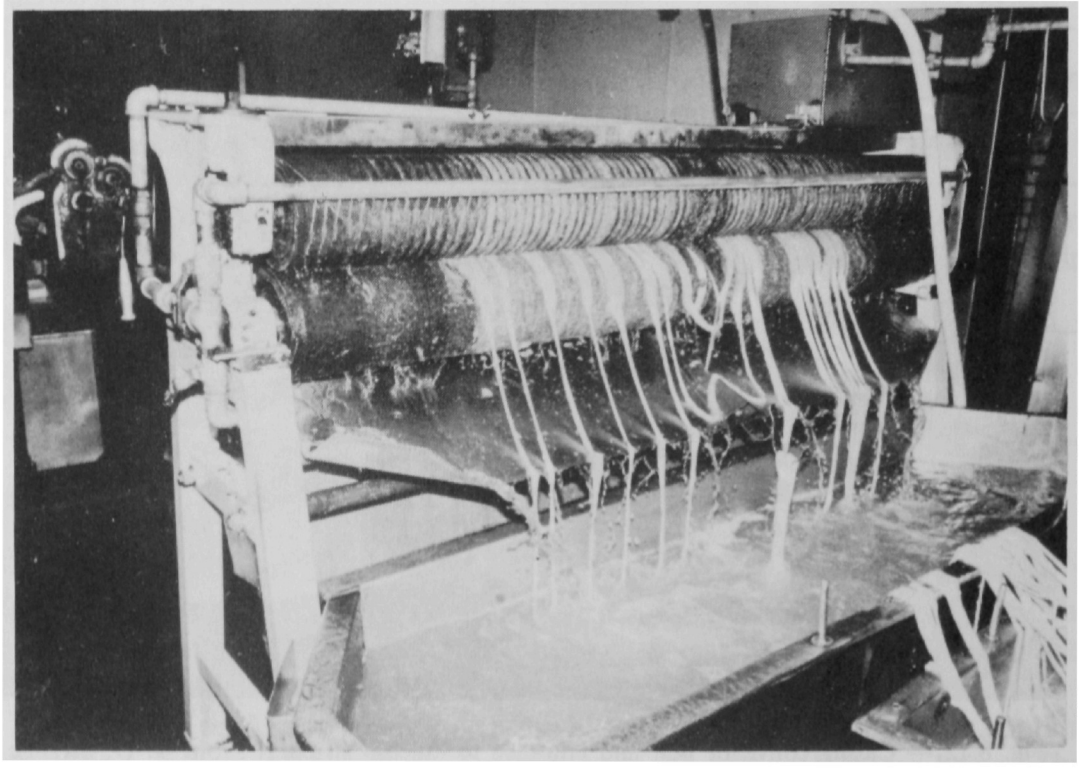


Fig. 8.14 — Exit end of mucosa stripper. From R. D. Strange (personal communication).

Fig. 8.15 — Entrance to finishing machine. From R. D. Strange (personal communication).

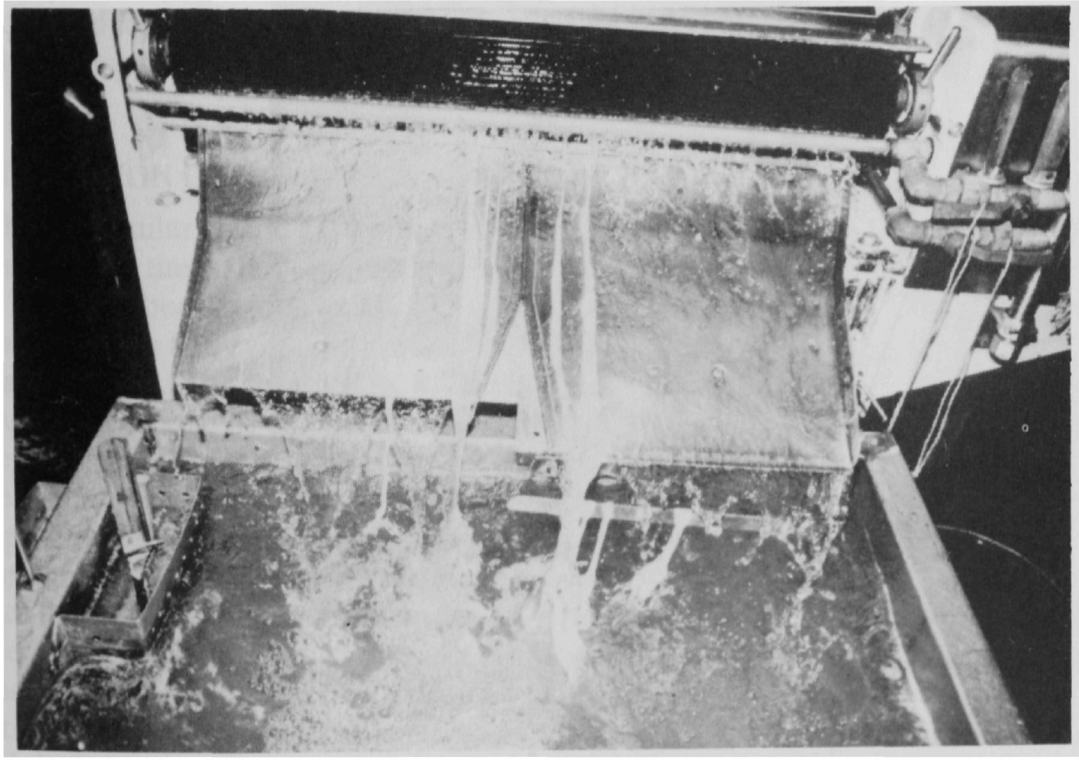


Fig. 8.16 — Exit end of finishing machine. From R. D. Strange (personal communication).

Table 8.8 — Component rollers of the finishing machine

Adjustable	Adjusted to	Water temperature	Cold adjusted
Scraping roll	Smooth stainless steel roll	41–42°C (105–108°F)	0.076–0.203 mm (0.003–0.008 in)
Smooth stainless Steel roll	Non-adjustable	41–42°C (105–108°F)	
Two small pull	Smooth stainless	10–16°C (50–60°F)	0.076–0.127 mm (0.003–0.005 in)
Through rolls of fluted rubber	Steel roll and to each other		

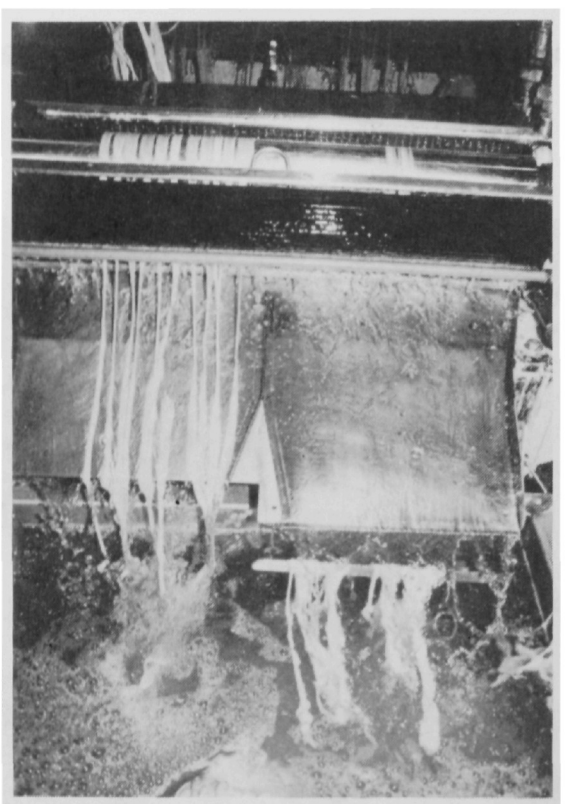


Fig. 8.17 — Finishing machine exit and tray with flipper. From R. D. Strange (personal communication).

Fig. 8.18 — Casing salting machine. From R. D. Strange (personal communication).

(blood). Slush packing requires more containers (fewer casings per container), less labour and less salt, but more care must be used to prevent oversalting which will make the bottom half of the container difficult to empty.

PRODUCTION OF LAMB CASING

Although similar to the production of hog casings, the harvesting of lamb casings uses different times, temperatures and roller adjustments. A New Zealand operation can be described as follows (Independent Casing Co., undated). The casings are removed from the evisceration tables and each lamb can produce 24 m (79 ft) of sausage casing. The first step is to separate the intestine from the other intestinal tissue. This is done by placing the crown set of gut and intestine onto a rotating bar. The crown sets are fed 10 at a time to this rotating bar, with the casing end hanging free so that it can be grasped by the operator. Next it is passed through a set of rollers (approximately 20 cm (8 in) in diameter) for partial cleaning and for expelling its contents. The remaining portion of the gut is utilized in the manufacture of fertilizer. Since the 24 m of intestine from one lamb is different in diameter from one end to the other and a uniform product is needed, the intestine is cut into three approximately equal links. These are referred to as A, B or first cut and C or second cut. These three sections of intestine are now referred to as runners. An operator strips off 50 cm (20 in) of outer membrane which is attached to each runner. This allows the cleaning process to be completed by machine at a later stage. The runners then go to a

cleansing bath for an overnight soak. Running fresh water is used in the soak and the casings are draped over stainless steel support rods. This cold water soaking stops the possibility of fermentation of the casings and also increases the ease of removing the mucus when the runner is introduced to the cleaning machine. The next day the runner goes into a trolley bath for an additional soak. The purpose of the trolley bath soak is to soften the casing even further. Thirty minutes later the casings are taken to the cleaning machine which contains rollers (approximately 30 cm (12 in) in diameter) and the outer membrane and all the soft mucus from the inside of the runner are stripped away. At this point the product is fully cleansed and can now be referred to as a casing. The next stage is grading, and the first step is to remove any short pieces that have been caused by breaks resulting from the handling up to this point. Casings are then sorted into various lengths according to packaging specifications. Some of the shorter casings are salted and packed into casts for export at this stage. The high quality casings, the traditional A and B or first cut that are 8 m (26.2 ft) in length will go to a selection and tubing department for added-value processing. At this stage, 8 m of natural casing are placed onto a tube (spool), which is used for ease of handling and time saving when sausage stuffing takes place since the plastic tube and consequently the casing can be fitted directly onto the stuffing horn. At the same time the casings are calibrated using running water, which swells the casing to its maximum diameter; a gauge is built into the tubing table to measure this diameter. The casing is then graded according to diameter and quality. There should be no more than 2 or 3 mm (0.078 or 0.118 in) difference between the diameter at one end of an 8-m casing and the other end. A casing graded 17 mm (0.669 in) therefore would be 17 mm at the narrow end and should be no more than 19 or 20 mm (0.748 or 0.787 in) at the other end. The water fed into the casing also serves to check it for perforations and therefore it can be graded for quality as well as size. Casings that are graded FQ (frankfurter quality) or 1A for quality are free from holes, whereas PQ (pork quality) or 1B casings are light to medium sprinklers. The casings are placed into one of 24 grading trays. The casings then go directly to the packaging room, where they are salted and counted and placed into polynet bags. About half the tubed and salted casings are packed for export at this stage. The casings salted and exported in polynet bags will have to be soaked again and desalted at the sausage-processing plant before they are ready for stuffing. The remaining casings, or the top third of the quality casings, are washed again to desalt them, placed in an edible preservative and then vacuum-packed with two hanks per pack. They are then placed in casts, pails or cartons for export. These vacuum-packed casings are the most convenient since they are ready to be stuffed as soon as they are unpacked and do not require an unsalting step.

Some portions of the intestinal tract are removed on the slaughter floor and handled separately from the intestines. Examples of some of these sausage containers are as follows:

HOG BUNG

The hog bung is pulled on the slaughter floor and removed from the encased fat. It is then tied with string at the end leading to the large intestine. Next, fat is trimmed

around the crown and the bung is turned inside-out and chilled in ice water. The bung is then graded according to size, salted, placed in bundles and packed in a container. For hog bung usage see Table 8.9.

Table 8.9 — Use of hog bungs

Used for	Width (in)[a]	Length (in)[a]	Approx. stuffing capacity (lb)[b]
Viskon-Lined sewed hog bungs			
Liver sausage	3½–3¾	30–32	7–8
Liver sausage	3–3½	30–32	5¾–6¾
Liver sausage	2½–3	30–32	5¼–5¾
Double wall — combined hog bung end and beef casing lined			
Liver sausage	3½–3¾	30–32	8½–10
Liver sausage	3¼–3½	30–32	7½–8
Liver sausage	3–3¼	30–32	6½–7
Liver sausage	2¾–3	30–32	5½–6
Liver sausage	2½–2¾	30–32	5–5½
Double wall — Hog bung ends			
Genoa	3½–3¾	20	5–5½
Genoa	3¾–4	20	5½–6½
Single wall			
Thuringer	3½–4	30–32	7½–8½
Thuringer	3–3½	30–32	6–7
Thuringer	2½–3	30–32	5–6

[a] 1 in=2.54 cm
[b] 1 lb=453.59 g
INSCA (undated).

HOG STOMACH

Hog stomachs are removed from the carcasses, trimmed free of fat, cleaned and washed, turned inside-out, slimmed and packed in salt. The stomachs are then drained but remain in salt until thoroughly cured.

BLIND END OR CAECUM

The blind end or caecum is separated from the intestine on the slaughter floor, washed on the outside, turned inside-out and rewashed. It is then salted and dried.

BLADDER

The bladder is removed from the carcass on the slaughter floor. Bladders are washed, turned inside-out, salted, and packed or inflated with air, fat trimmed and then chilled in water, salted and graded or reinflated and dried. If dried, they are often softened with steam, flattened and then packed.

BEEF BUNG

The beef bung (caecum or blind gut) has the outside fat removed, is turned and hand-cleaned. Bung gut-skins are often saved from the beef bungs, these shiny membranes are the outside (peritoneal) covering and are used by craftsmen who make gold leaf. This removal does not affect the bung as a sausage container. The bungs are then graded.

WEASAND

After the muscle tissue is removed from the outside of the weasand, it is washed, turned inside out and inflated with air, dried in a warm room and graded.

CHITTERLING

The hog's middle intestine or black gut is 3.7–4.3 m (12–14 ft) in length and weighs approximately 2.3 kg (5 lb). The hog's middle intestines are frequently sold as an edible chitterling product. After the middle intestine is removed from the carcass, it is trimmed free of fat. A perforated pipe is then run inside the intestine and a steady spray of water is used to clean the intestine. It is further cleaned on a casing defatting machine or can be split and cleaned by hand. If the casing is not split, it is turned, cleaned a second time and then placed in ice water to chill and bleach. Sometimes the unsplit intestine is heavily salted (this helps to loosen the mucosa), turned mucosa-side out, washed in a tripe washer and rechilled. The chitterlings are then drained, held overnight at 1–2°C (34–36°F) and the pink-coloured chitterlings may be merchandized fresh (the colour is not very stable). The chitterlings may also be frozen for shipment. In some cases, chitterlings are dry cured. To dry cure, they are packed in layers of salt and overhauled in three days. They normally contain 30% salt by weight after curing. Chitterlings may also be placed in 100% brine after chilling and shipped (if not shipped in 7 days, they should be overhauled or resalted) in this strong pickle. They should not cure longer than 15 days. Chitterlings may also be cooked (boiled for 2 hours), chilled overnight, packed and shipped in 100° (saturated brine) pickle.

OTHER USES FOR INTESTINAL PRODUCTS

Uses, other than for manufacturing sausage casings, of intestinal-type products include pepsin and heparin extraction (see Chapter 7), edible uses (see Tripe and

Intestines sections in Chapter 2 and Chitterling section in this chapter), strings for musical instruments (usually from sheep), strings for sports rackets (mainly from sheep), catgut (surgical ligatures, mainly from sheep), and for beating gold leaf (see Beef bung section in this chapter) to reduce its thickness.

Musical instrument strings would include strings for the harp, cello, double bass, guitar, banjo, mandolin, ukulele, and violin. Gut cables are also used in some clocks and other mechanical devices.

The tennis racket string requires 7.3 m (24 ft) of small intestine from a sheep. To manufacture sports racket strings, the intestine is first split, then chemically treated, spun (1–100 ply, 28 ply of smooth gut or 11 of whole gut is normal) into shape, again chemically treated and then dried on frames (3–15 days). They are then turned (10 minutes) on a finishing machine and polished until smooth. The strings are tested for tensile strength, uniformity of diameter and for stretching ability.

Surgical ligatures are made from the strong, silky side of narrow sheep intestines. The advantage of this type of thread is that it is made from plain biological gut and it can be absorbed by the body; therefore, the stitches do not have to be removed. The time required for the stitches to be absorbed can be controlled by the manufacturing technique, and some of the gut sutures are used as removable sutures. The foreign-body reaction caused on the wounds by the natural surgical guts are different from that produced by silk or nylon sutures and may be desired to promote firmer scar and healing in some cases. The biological sutures are usually stored in isopropyl alcohol (C_3H_8O) and sterilized either by gamma radiation or by ethylene oxide (C_2H_4O).

MUCOSA

Mucosa is the slime or inner membrane of the casing, which, when soaked and crushed, is removed by squeezing by the mucosa stripper(s) or crusher(s). The mucosa is used by the pharmaceutical industry to make heparin (see Chapter 7) which is used in medicine as an anticoagulant (Strange, 1986). The yield of mucosa should range from 612 to 1134 g (1.35 to 2.5 lb) of mucosa per hog slaughtered. The mucosa, containing as little water as possible, should be placed in a mixing tank. Mucosa at approximately 0.874 g/cm^3 (7.3 lb/gallon) is lighter than water. The liquid mucosa should contain 14–16% solids. To preserve the mucosa, it should be thoroughly mixed with sodium bisulphite ($NaHSO_3$) at a rate of 0.25 (cold weather) to 0.33 (hot weather) pounds of bisulphite per pound of mucosa. This can be mixed for no more than 5 minutes with air (5.6 kg/cm^2 (80 psi)) but prolonged mixing will drive off as a gas some of the sodium bisulphite. The reduced level of preservative may cause the product to spoil. Upon storage, solid mucosa will form and float on top of the water layer.

YIELD AND STORAGE

The yield of beef, pork, sheep and goat casing may be found in Table 8.10. The yield of pork casings will range from 20 to 26 head of hog per bundles. Twenty-five to 50 bundles are often packed per barrel, resulting in 600 to slightly over 1000 casings per barrel. The barrels will have a gross (including the barrel) weight of from 213 to 249 kg (470 to 550 lb).

After packing, the casing containers should ideally be stored and/or shipped in a cool (less than 10°C (50°F)) area or vehicle but since they are salted they should not spoil in heated storage. However, if the temperature is too warm they will discolour and develop a very objectionable off odour, neither of which can be removed by pre-flushing.

Table 8.10 — Yield of casing per animal

	ANIMAL			
	Beef	Pork	Sheep	Goats
Round length (ft)[a]	90–135		90	75
Small casing length (ft)[a]		45–52		
Middles length (ft)[a]	20–25	12–16		
Bung length (in)[b]	48–54	30–74		
Middle cap length (in)[b]		10–12		
Weasand length (in)[b]	18–26			
Bladder width (in)[b]	7–14	5–9		

[a] 1 ft=0.3048 m
[b] 1 in=2.54 cm
FAO of UN (1962), Institute of Meat Packing (1958).

COLLAGEN CASING

Collagen casing can be manufactured in both an edible (usually small casings) and a non-edible (usually large casings) variety (Ockerman, 1985). The small casings are chewable because they are thin and in edible form they will solubilize in cooking. Collagen casings are often considered the 'bridge' between artificial and natural casings and are manufactured to contain fresh, smoked, dried and processed sausage products. Collagen is extracted from the corium layer of inspected, soaked, salted and rinsed animal hides (normally beef) and extruded into the shape of a casing. If the casings are to be kosher, the starting hides must also be kosher, from kosher-slaughtered animals, and a separate set of processing equipment is used solely for producing Kosher casings (Pakfacts, 1983; Devro, 1979). After production, collagen casings should be stored between 2 and 10°C (35° and 50°F) to prevent bacterial spoilage.

These casings are 'man-made' products but are constructed from collagen, a protein of animal origin which is normally obtained from the central corium layer of beef hides. Two methods of manufacture are used. They are referred to as the 'dry and wet' methods. The dry method has a high solid content and the wet method uses a gel or low solid content for extrusion.

Hides are washed, defleshed and treated with a weak acid or alkali to remove the hair from the follicle. The hide is then split by machine to separate the outer grain or leather layer from the inner collagenous corium layer. The corium layer is then

neutralized, washed and coarsely ground. This ground corium is then run through a high-speed ultra-fine chopper, resulting in a shammy. The shammy, containing 5% collagen (low solids), is acidified with acetic acid ($C_2H_4O_2$), causing it to absorb water, and the pasty gel is then filtered, homogenized (to randomly-orient the fibres for uniform stretch and burst strength) and extruded. The extruder aligns the collagen fibres and fibrils by running them through an annular die and produces a continuous, uniform tube with uniform length, diameter, wall thickness and strength.

The extruded tube is neutralized, washed with water and given a chemical treatment to improve strength (sugar) and pliability (glycerine). The casings are then dried under special temperature and humidity conditions, and then are cut and shirred to fit most stuffing horns. The casings are then packed in moisture-checked boxes. Moisture is maintained between 13 and 18% and the boxes are then sealed. The product can be stored indefinitely as long as the storage conditions remain favourable. The casings are ready to use when they come from the box (no rewetting is necessary except for large diameter casings, which can be soaked in 27–32°C water (80–90°F)). These casings have predictable handling and stuffing characteristics and can be used in programmable weight systems.

The sausage in these casings should be cooked at a relative humidity of 40–45%. If cooked below this relative humidity, the casing will split, and if cooked above, the casing will hydrolyse and spill the emulsion.

The small casings are edible and are often used for fresh pork sausage. Large collagen casings are treated with aldehyde to cross-link the collagen and increase the strength. This type of casing is removed before consumption.

Collagen casings are available (Coria, 1983; Devro, 1984) in the forms listed in Table 8.11.

These casings are typically supplied in natural colour, but are also available in red and smoke colour. They are also available with ends for twist linkers or with pre-closed ends.

Ground sage will often discolour collagen casings. Formaldehyde (CH_2O) is used in the manufacture of collagen casings and is present on these casings in both the free and combined state (Table 8.12).

Table 8.11 — Types of collagen casing

Fresh Sausage Casing	
Diameter	17–30 mm (0.669–1.181 in)
Length	10.67–21.34 m (35–70 ft)
Length (shirred)	19–25 cm (7.48–9.84 in)
Deep-fat frying casings	
Diameter	17–29 mm (0.669–1.142 in)
Length	10.67–15.24 m (35–50 ft)
Length (shirred)	14–29 cm (5.51–11.42 in)
Processed meat casing and dry and semi-dry sausage casing	
Diameter	19–40 mm (0.748–1.575 in)
Length	7.62–15.24 m (25–50 ft)
Length (shirred)	23 cm (9.06 in)
Large-diameter fresh sausage casing	
Diameter	23–34 mm (0.906–1.339 in)
Length	10.67–15.24 m (35–50 ft)
Length (shirred)	19–25 cm (7.48–9.84 in)
Frankfurter casing	
Diameter	19–28 mm (0.748–1.102 in)
Length	11.43–19.81 m (37.5–65 ft)
Length (shirred)	19–29 cm (7.48–11.42 in)
Beef stick casing	
Diameter	12–28 mm (0.472–1.102 in)
Length	11.28–15.24 m (37–50 ft)
Length (shirred)	22–30 cm (8.66–11.81 in)

Coria (1983); Devro (1984).

Table 8.12 — Permitted formaldehyde levels for collagen casings

	USDA Maximum	
	Free	Combined (total−free)
Edible	None	4 ppm
Inedible	10 ppm	200 ppm
Inedible ring bologna	50 ppm	200 ppm

REFERENCES

Coria (1983) *Coria edible collagen casing.* Teepak, Chicago.

Devro (1979). *Ace Devro collagen casing natural.* Devro, Somerville, New Jersey.

Devro (1984) *Collagen and fibrous casing and equipment for the meat industry.* Devro, Somerville, New Jersey.

FAO of UN (1962) *Animal by-products processing and utilization.* Prepared by I . Mann. FAO of UN, Rome.

Independent Casing Company (undated) *A natural case in case.* VCR tape.

INSCA, (undated). *Facts about natural casings.* International Natural Sausage Casing Association, Chicago.

Institute of Meat Packing (1958) *By-products of meat packing industry.* Committee on Textbooks of the American Meat Institute, University of Chicago, Chicago.

International Trade Center (1973) *Animal casings.* International Trade Center, UNCTAD/GATT, Geneva, Switzerland.

Ockerman, H. W. (1983) *Chemistry of meat tissue.* Department of Animal Science, Ohio State University, Columbus, Ohio.

Pakfact (1983) *50th Anniversary Issue.* Teepak, Chicago, Illinois.

Strange, R. D. (1986) *Stridhs 1700.* A VHS tape. R. D. Strange, Smithfield, Virginia.

9

Blood utilization

INTRODUCTION

Animal blood has many possibilities for use in the food, feed, laboratory, medical, industrial and fertilizer areas, and some of these uses are summarized in Table 9.1.

Table 9.1 — Uses of animal blood

Food	Emulsifier, stabilizer, clarifier, colour additive, nutritional component.
Feed	Lysine supplement, vitamin stabilizer, milk substitute, nutritional component.
Fertilizer	Seed coating, soil pH stabilizer, mineral components.
Laboratory	Tissue-culture media, tannin analysis, active carbon, haemin, blood agar, peptones, glycerophosphates, albumins, globulins, sphingomyelins, catalase.
Medicine	Agglutination tests, immunoglobulins, fractionation techniques, blood clotting factors, sutures, fibrinogen, fibrinolysin, fibrin products, serotonin, kalikrenins, plasminogen, plasma extenders.
Industry	Adhesive, resin extender, finishes for leather and textiles, insecticide spray adjuants, egg albumin substitute, foam fire extinguisher, porous concrete, ceramic and plastic manufacturer, plastic and cosmetic base formulations.

Divakaran (1980).

Effective removal of blood during slaughter is required by the Moslem and Jewish ritual slaughter procedure and is probably historically based on the fact that carcasses of improperly bled animals discolour more quickly and have reduced

keeping qualities. In spite of this, blood is usually sterile in a healthy animal and is high (17–18%) in protein that is reasonably well balanced in amino acid composition.

Blood in food is used as a protein supplement, as a textured meat protein, to clarify liquid foods (e.g. wine), as a stabilizer (e.g. cheese), as an emulsifier (e.g. butter) and as a colouring agent for meat (particularly poultry) items. Blood albumin has been used as a substitute for egg albumin in food, utilized in making sausage casing and incorporated into bread flour.

Most of the blood used in livestock feed is in the form of blood meal used as a protein supplement. Production of blood meal consists of cooking the blood, expressing the excess water and drying to obtain a granular product. Blood meal is deficient in the amino acids tryptophan and isoleucine, but is a rich source of lysine. Lysine content varies with the method of drying from 10–12% with spray drying to 6–8% with vat drying. Ring drying (flash drying) increases considerably the biological availability of lysine in the dried meal. Blood meal has also been found to be useful as a stabilizer for fat in bone meal and in livestock rations and is an excellent source of most of the trace minerals.

In the laboratory, there are many uses of blood products and the most common ones would include uses as a nutrient for tissue culture media and as a necessary ingredient in some agar for bacteriological use. Many blood components are isolated and used in chemical analysis or as nutritive supplements. Modified blood components are also used in the biological assay of heparin and used as standard solutions in the calibration of instruments used in haematology. Blood plasma has also been used as a diluent for semen from boars and bulls.

Industrial uses of blood include as an adhesive and for its film-forming properties in the paper, lithographic, plywood, veneering, fibre, plastics, and glue industries. It also finds use in insecticide and fungicide formulations, in foam fire extinguishers, in moulded ceramic products, in leather finishers, in cork crowns, in porous concrete and as a stabilizer for biological material and drugs.

Blood is also useful as a fertilizer and, in addition to contributing nitrogen, it aids in humus formation and improves the soil structure. Blood is also useful in seed coating and regulating soil pH. Disadvantages of blood spread on the soil are that it will attract rats and vermin.

UTILIZATION OF BLOOD

Use of blood in blood sausage, pudding, soup, bread or crackers is briefly discussed in Chapter 2. However, the addition of more than a small percentage of blood to meat items renders the end-product dark and often unpalatable, and the use of only plasma utilizes only a minor part of the blood protein. In spite of this, frozen plasma is mixed with emulsion meat products to a limited extent in some countries. Since blood makes up such a significant portion (6–7% of the animals' usable protein) of the animal's mass (2.4–8% of the animals' live weight; dried blood makes up 0.7% of live weight) and since new techniques are being developed to utilize this high protein (18%) product, some of the newer and innovative approaches will be discussed in this chapter. Normally approximately 50% of the blood is collected during bleeding in the slaughter operation. The remaining blood (approximately 50%) is retained in the capillary system throughout the body. Table 9.2 shows the average amount of

Table 9.2 — Typical blood yields recovered at slaughter

Species	Blood (80% moisture) per 1000 lb live weight		Blood per average animal (l)	Dried blood weight (10% moisture) (parts per 1000 live weight)
	(lb)[a]	Gallons[b]		
Average if 100% of blood is collected	77.0	7.2	—	17.0
Cattle (approximately 50% collected)	32.6–33.7	3.1–3.2	10–12	7.2–7.5
Calves (approximately 50% collected)	25.8–27.0	2.4–2.5	—	5.7–6.0
Sheep (approximately 50% collected)	24.8–31.5	2.3–3.0	1.5	5.5–7.0
Swine (approximately 50% collected)	29.2–35.1	2.8–3.4	2.5	6.6–7.8
Chickens (approximately 51% collected) 300 s bleed	42.1	3.9	0.2/2 kg bird	9.3

[a] 1lb = 454 g.

[b] 1 gallon = 3.79 l.

Source: Kotula and Helbacka (1966), Wismer-Pederson (1979), Newell and Shaffner (1949), Stevenson (undated).

blood that can be expected in a typical slaughter operation. Half a kilogram (1 lb) of nearly pure protein can usually be salvaged per beef animal.

R. Strange (personal communication) and Wismer-Pederson (1979) described the latest blood utilization techniques and much of the following information is a summary of their reports.

In small slaughter plants blood is often allowed to escape down the drain, and this represents a sizeable environmental pollution hazard since the release of blood in this manner will increase the biochemical oxygen consumption of the sewage in the average plant approximately ten-fold and will increase its suspended solids approximately three-fold. Blood, of course, could be simply dried and processed into blood meal or mixed and dried with meat and bone meal, but this downgrades blood to a non-human use and also lowers the protein availability. This approach does have the advantage of increasing the lysine content of the meat meal or the bone meal and consequently improving the biological utilization of these meals by animals.

Blood taken from healthy animals is essentially sterile and, if collected from the

stick wound from beef animals that have been approved by the inspection service, it still remains in the area of 'food for human consumption' in the U.S. Collection often involves a specially designed hollow knife or thief knife to which a hose is attached that allows the blood to flow into a container (see Fig. 2.1). Anticoagulants are usually added in the hollow knife. After all the animals have passed inspection whose blood was collected in a common container, the blood is released for human utilization. If any animal of the group does not pass inspection, then the blood from the container is not utilized for human use. The blood that passes inspection is normally then pumped into a centrifuge (specific gravity of whole blood 1.042–1.056, corpuscles 1.084–1.098, plasma 1.019–1.029) where the blood is separated into blood plasma and erythrocytes (see Fig. 9.1). The blood fractions are then chilled and pumped into storage tanks.

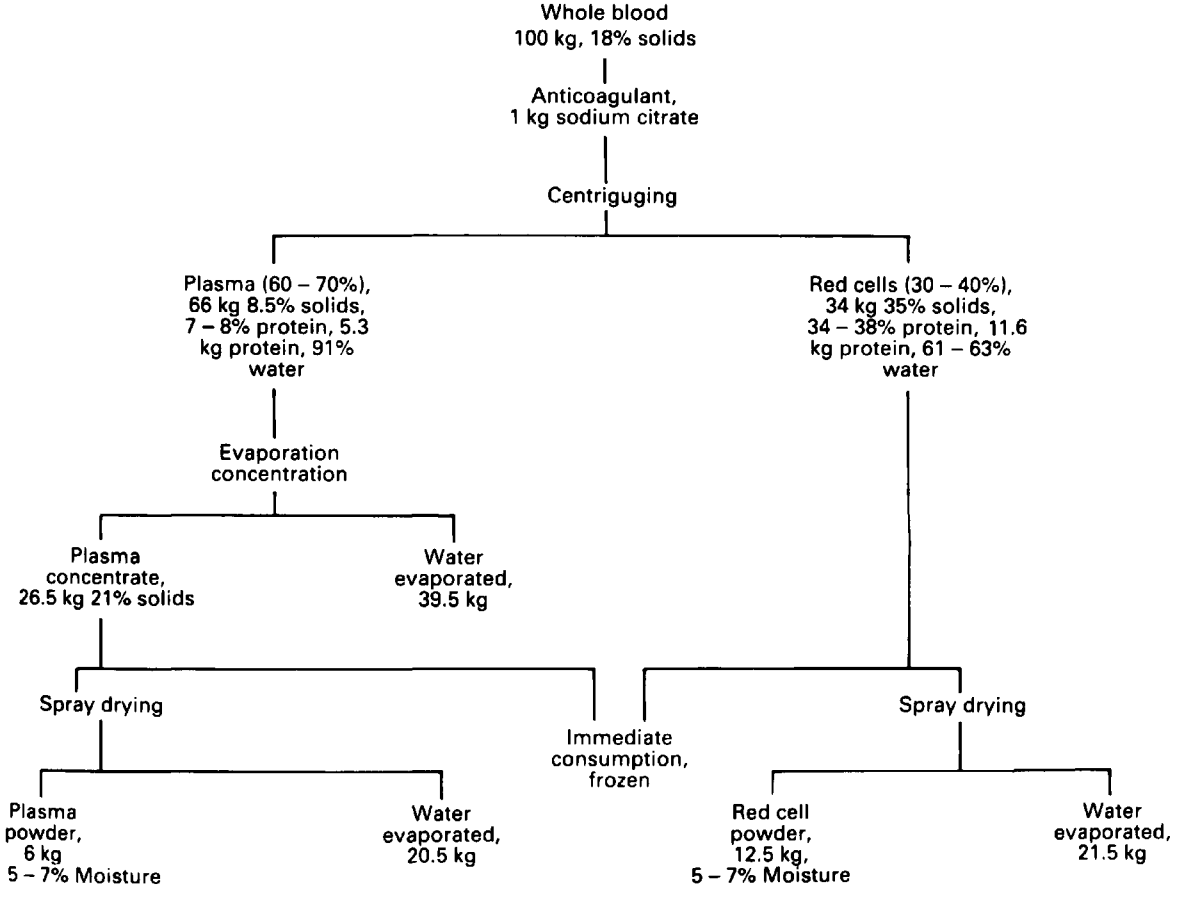


Fig. 9.1 — Separation of blood into dried fractions. From R. D. Strange (personal communication) Filstrup (1976), Wismer-Pederson (1979), Westfalia Separator (undated).

For beef blood collection (the only blood approved in the U.S. for several years because it was the only type that the inspection service thought could be collected in a sanitary manner), an approximate 10×15 cm (4×6 in) section of the hide in the area of the neck where sticking will take place is removed to avoid as much contamination as possible. In pigs this area is sanitized by applying a gas torch (singeing) and

shaving. The hollow knife, which is approximately 13 cm (5.1 in) long (cattle), is then inserted into the artery area in the neck for sticking. After bleeding, blood clots in 3–10 minutes, depending on environmental temperature, and this is caused by thrombin (enzyme), which converts soluble fibrinogen in the blood into insoluble fibrin. Clotting does not occur in circulating blood due to natural anticoagulants present. Normally an anticoagulant is supplied to the knife-point through a hollow pipe in the knife handle. If blood is driven into the knife by the animal's heart-beat, the blood yield is normally a function of the time the knife is left inserted into the carotid artery–jugular vein area. A 60-second collection time will usually yield approximately 10–14 l (2.6–3.7 gallons) of blood per adult beef animal and after 60 seconds the flow rate is reduced. Extension of this collection time to 90 seconds will yield approximately an additional 2 l (0.5 gallon) of blood. Normal bleeding times used in industry are 6 minutes for cattle, 4–5 minutes for sheep, 3–4 minutes for calves and 6 minutes for pigs. Hogs will yield approximately 2.5 l (0.7 gallon) of blood, sheep 1.5 l (0.4 gallon) and young chickens approximately 10% of their body weight.

An anticoagulant of trisodium citrate (sodium citrate, $C_6H_5Na_3O_7$) or citric acid ($C_6H_8O_7$) in the amount of 0.2% with or without water (2 parts water to 1 part sodium citrate or citric acid) is normally used. A solution of 150 kg (330.7 lb) of citrate and 300–400 l (79–106 gallons) of water is prepared and 0.5 l (1.1 pints) of this solution is used per 15 l (4 gallons) of blood. A mixture of phosphates has also been used as an anticoagulant and this mixture would contain 22% of Na_2HPO_4, 22% $Na_4P_2O_7$, 16% $Na_2H_2P_2O_7$ and 40% NaCl. This mixture is normally used at the rate of 10 g (0.353 oz) of the mixture per litre (2.1 pints) of blood. Also heparin or oxalates have sometimes been used.

Anticoagulants function in a variety of manners and some of them are as follows. Heparin is the natural blood component that helps prevent coagulation in the live animal during blood circulation. Commercially it is available in the sodium, lithium or calcium salt and it inhibits the formation of thrombin from prothrombin. It is often used at the rate of 200 mg/l of blood when the blood is to be used in the food or pharmacological areas. Sodium ($Na_2C_2O_4$) or potassium oxalate ($K_2C_2O_4$) may be used at the rate of 1 g (0.035 oz) of a 30% solution in water per litre (2.11 pints) of blood or any concentration dissolved in 0.85% sodium chloride (NaCl) solution of 1 g/l (1000 ppm) of a mixture of 3 parts ammonium oxalate ($Al_2(C_2O_4)_3$) to 2 parts of potassium oxalate dissolved in a small quantity of water or diluted in a saline solution. Oxalates precipitate calcium needed for coagulation. They are poisonous; therefore, they cannot be used where the blood component is going into the food or pharmaceutical area. Sodium citrate ($Na_3C_6H_5O_7$) is used as the rate of 3 g/l (3000 ppm) of blood and it converts the calcium into a non-ionized form, preventing coagulation. Regulations for the use of citrate in the food and pharmaceutical industries vary from country to country. Ethylenediaminetetra-acetic acid disodium salt (EDTA, $Na_2C_{10}H_{14}N_2O_8$) is used at the rate of 2 g/l (2000 ppm) and acts by chelating the calcium ion needed for coagulation. It is permitted in the food and pharmaceutical industries in most countries. Proteolytic enzymes have also been used in place of anticoagulants to produce products with high protein quality and containing low levels of ash (Quaglia and Massacci, 1982). The anticlotting effect of these enzymes is produced by the proteolytic activity on fibrin. Rapid chilling of

blood to 1–2°C (34–36°F) will prevent coagulation without an anticoagulant, but the blood will coagulate when the temperature increases. Vigorous stirring of blood will cause the fibrin to adhere to the stirring rod and prevent coagulation, but this process damages the red blood cells.

The blood usually flows from the sticking knife into the holding container by means of gravity. Application of vacuum suction may or may not be used because vacuum will sometimes collapse the animal's blood vessels and block the flow of blood into the knife. The knife is sterilized between each sticking operation. The number of cattle from which blood is collected into one tank is determined by the likelihood of condemnation of a carcass, which in turn would contaminate the whole tank of blood, and by the time lapse between slaughter and meat-inspection carcass approval. A collection tank has also two arrangements for the removal of blood: one for approved blood and the other for condemned blood.

Collection of blood from swine (after 30 seconds' blood flow is reduced) is normally more complicated than for beef animals because of the faster slaughter-line speed.

Approved blood from either species may be next pumped into a plate cooler and then to insulated storage tanks. It may be processed as whole blood or the blood is pumped to a centrifuge (a solid-wall, disk-type bowl is often used) which continuously separates light plasma (52–70%) from the heavy erythrocytes (red blood corpuscles; 30–48%). After centrifugation, the separated fractions, if not previously cooled, are cooled from approximately 35°C (95°F) to 2°C (36°F) in order to minimize bacterial growth. The various fractions are then pumped into storage tanks for holding or for freezing prior to shipment. The fractions may be frozen in a flake-ice machine and distributed in the frozen state, or they may be dried (drying often results in off odours). Beef plasma which contains globulins, albumins and fibrinogen (in 3–10 minutes the enzyme thrombin converts fibrinogen to fibrin which is responsible for clotting) should be yellow or orange and pig plasma should be grey–white to pink. The darker colour of the plasma is due to haemoglobin, either because of incomplete separation or because of haemolysis of the erythrocytes. Haemolysis (lysis) can normally be prevented by careful mechanical handling of the blood in pipes, joints and valves and by minimizing dilution of blood with water from the cleaning operation. Additional water in the blood will decrease the osmotic pressure in the plasma, which may result in the bursting of the erythrocytes. Beef blood seems to be less sensitive to mechanical disruption than is pig blood. Also, there is a bigger difference between plasma and erythrocyte specific density in beef blood than in pig blood, making centrifugal separation easier. Maintaining good hygiene of the blood-collection system is essential; most collection units have automatic cleaning devices and some clean with: (1) 5 minutes of cold-water rinse; (2) 15 minutes of lye (potassium (KOH) or sodium hydroxide (NaOH)) solution cleaning; (3) 15 minutes of acid-solution cleaning; and (4) 5 minutes of cold-water rinsing. If good hygiene is maintained, the bacterial quality of the blood should be less than 2000 total plate-count organisms per ml of blood and remain constant for a few days if stored at a temperature of 2°C (36°F). After being hygienically collected, in most cases, whole blood can be stored for 4 days at 2°C (36°F) before the bacterial count starts to increase dramatically. Blood is often stored between 0 (32°F) and 2°C (36°F) and a storage life of 4–6 days is possible. If strict hygiene standards are not

followed, blood may have as many as 2.5×10^5 organisms/ml of blood at collection and rapidly increase during storage. After centrifugation of the blood, 20–25% of the bacteria will appear in the plasma and the remaining 75–80% in the erythrocyte fraction. Therefore, blood plasma should contain a fairly low bacterial count of approximately 1000/ml of plasma.

When blood fractions are to be held for extended periods of time, the components are normally frozen or dried.

The compositions of blood components are given in Table 9.3. Table 9.4 gives a more complete composition.

Table 9.3 — Composition of blood components

	Blood	Blood plasma	Red blood corpuscle concentrate	Dried plasma	Dried globin
Dry solids (%)	18–20	8–9	28–37	96–97.5	96.5
Protein (%)	13–15	6–8	28–38	70–96	91–95.4
Albumin fraction (% of protein)		50			
Globulins (% of protein)		23–27			
Fibrinogen (% of protein)		17–23			
Fat (%)	<1	0.1–1	1	0–1.5	0
Carbohydrate (%)	<1	<1	<1	—	—
Salts (%)[a]	2	1.5	1–3	2 or less	1–6
Water (%)	80–82	90–91	61–63	2.5–7.0	3.5

[a] Level depends on quantity and type of anticoagulant used.

Chemical preservation can also be used if the blood is intended for non-human use. Chemicals such as 1% sodium bisulphite ($NaHSO_3$) and acids like hydrochloric (HCl), phosphoric (H_3PO_4), formic (CH_2O_2) or sulphuric (H_2SO_4) at a concentration of 0.25 N or ammonia (NH_3) at a concentration of 0.25–0.50% can be used. Some people have suggested preserving blood to be used in human food by adding lactic acid ($C_3H_6O_3$) to coagulate blood or increasing its stabilization by using such compounds as sodium citrate ($Na_3C_6H_5O_7$) and antifungal agents such as sorbic acid ($C_6H_8O_2$) or propionic acid ($C_3H_6O_2$). To freeze blood plasma it is normally placed on a vertical rotating drum that has a temperature of between −10°C (14°F) and −40°C (−40°F) and then scraping the frozen plasma from the surface in the form of flakes. If the frozen flakes are added to chopped food, it will cool as well as function as an additive. When blood is dried, great care must be taken in order that

Table 9.4 — Blood composition

	Centri-fuged liquid blood plasma of blood	Dried blood plasma	Centri-fuged blood corpuscles 40% 60% of blood	Dried globin
Chemical				
Moisture	90–91%	2.5–7.0%	61–63%	3.5%
Protein	6.5–8.0%	70–96.0%	28–38%	91–95.4%
Salt[a]	1–2%	<2.0%	1–3%	1–6%
Na		8.5%		0.60%
Cl		9.9%		5.10%
K		0.3%		0.03%
Ca		0.1%		0.03%
Mg		0.03%		0.02%
Lipids	0.1–1.0%	0–1.5%	1%	0
pH	7.5–8.5			
Bacteriological				
Total count	Max 100 000/g	Max 100 000/g		
Normal	<10 000/g	<50 000/g		300/g
Coliform	Max 100/g			
Spores	Max 120/g	Max 1000/g		
Usual		<120/g		
Sensory				
Odour	Neutral	Neutral		
Taste	Bland	Neutral		
Colour				
Beef (uncooked)	Orange	Pale yellow-pale orange		
Beef (cooked)	Yellow			
Pork (uncooked)	Yellow	Pale yellow		
Pork (cooked)	White			
Solubility				
Should be		90–100%		
Normal		75–80%		

[a] Most is due to anticoagulant addition.

Source: R. Strange (personal communication), Filstrup (1976), Braathan and Nilsen (1982), Dill (1975), Stevenson (1979), USDA (undated), Bengtsson and Holmquist (1984), Satterlee (1975), Ellco Protein AB (undated).

denaturation of the protein is kept to a mimimum since this lowers the quality of the dried fraction. It is usually more economical to first concentrate the blood plasma prior to the drying process. In most plants concentration is accomplished by evaporation, but some work has been reported on membrane filtration as a method of concentration. Membrane filtration is accomplished by passing plasma under pressure across plastic filter membranes, which will permit water and salts to be

removed. There are two primary ways of evaporation concentration: the falling-film evaporator and the centri-term evaporator. In the falling-film evaporator, there is a vertical battery of steel plates surrounded by a steam jacket. The plasma flows down the 12 cm (34.4 ft) inner periphery of the pipes as a thin film, which is spread out by the steam evaporated from the liquid. The evaporator normally operates under a vacuum, which gives the plasma a boiling point of approximately 36°F (97°F), and the plasma is normally concentrated from about 8% to approximately 25–27% dry matter. In the centri-term evaporator, the liquid film on the evaporator surface is spread out by centrifugation. There are six rotating cones which make up the evaporation area and these are heated with steam. The cones rotate at a speed of approximately 600 revolutions per minute, which drives the plasma from the centre to the edge of the cones in approximately 1 second. This short drying period reduces the amount of protein denaturation.

Normally the next step is spray-drying of the concentrated plasma. The basic principle is that the plasma is atomized into minute particles and is immediately contacted with a flow of hot air. This technique of spray-drying has the following advantages which reduce contamination: (1) the temperature of the blood plasma is relatively low even though the drying air is at a much higher temperature; (2) the temperature of the plasma does not approach the temperature of the drying air until a major portion of the water has been removed, thus minimizing protein denaturation; and (3) as evaporation takes place from a large surface area and the time of drying is only a matter of a few seconds, this also minimizes denaturation.

Generally the concentrated plasma is dispersed into the inlet air stream by a centrifugal atomizer with a rotating drum, which spins at approximately 16 000 rpm and has a diameter of 160 mm (6.3 in). This causes the liquid plasma to be atomized into extremely fine droplets. Heated air is also fed into the top of the chamber together with the atomized plasma. Inlet air usually has a temperature of 130–160°C (266–320°F) which falls to approximately 65–70°C (149–158°F) at the outlet. Inlet air temperatures of up to 200°C (392°F) appear also to give satisfactory results. The very large surface area of the atomized plasma when contacted by the hot air stream causes violent evaporation to take place. This evaporation causes cooling and keeps the temperature of the droplets reduced to a level such that excessive denaturation is avoided. Dried particles are 75 μm in size when drying is completed and they are removed from the bottom of the chamber and quickly chilled in order to prevent deterioration.

Fluidized-bed drying has also been used to dry plasma, with even less loss of solubility and other technical properties. This type of drying consists of spraying the plasma on to a bed of small plastic polycarbonate balls that are suspended in a stream of warm air. The plasma coats the ball with a thin film and this thin layer of moisture quickly evaporates. The balls are forced against a wire screen, dislodging the dried powdered plasma, which is then collected. This system is generally more economical to operate than a spray-drying system.

When plasma is dried it normally has a high salt concentration, which is usually due to the added anticoagulant. The salt content can be lowered by ultrafiltration of the concentrated plasma through a membrane which allows small molecules to pass. Membranes with a cut-off value of approximately 350–500 molecular weight are usually used. Filtration is normally conducted at a temperature of 50°C (122°F).

When ultrafiltration and spray-drying are used a dried blood plasma can be produced with 96.4% protein and 2.5% moisture.

The erythrocyte fraction has approximately 35% dry matter and can be dried without concentration. Generally, separate spray dryers are used for erythrocyte and plasma drying due to the difficulty of cleaning of the unit to avoid plasma colour formation.

GENERAL PROPERTIES OF BLOOD FRACTIONS IN FOOD

It should be noted that blood is composed of cellular and liquid components. If anticoagulants are added and erythrocytes are removed by centrifugation from liquid blood, then the remaining liquid is called plasma and contains fibrinogen (protein). Plasma differs from blood serum, which is obtained when blood coagulates, because the serum does not contain fibrinogen.

Utilization of plasma

Blood plasma, upon heating, forms a gel, and if plasma is boiled for 15–20 minutes the plasma will solidify, similarly to an egg white. When plasma proteins denature, the proteins undergo polymerization, probably by an amine–carboxylic acid condensation, forming a gel. As solidification occurs, the gel will entrap fat, and water is released from the protein matrix. The volume expands and the strength of the gel increases linearly with temperatures between 75°C (167°F) and 95°C (203°F). The gel structure develops slowly and it requires approximately 1 hour of heating to get a maximum gel strength at 90°C (194°F). Gel strength is also increased with increased salt concentration and with increasing pH. Gel formation is linked with the denaturation of the protein molecule, which occurs at a temperature between 67°C (153°F) and 73°C (163°F) and a pH between 5.8 and 6.8. As denaturation occurs and the peptide chain unfolds, new reactive areas are exposed. Reactions between hydrophobic areas, the formation of –S–S– bonds and electrostatic interactions of charged groups occur on the surface. Some researchers suggest that amine–carboxyl condensation is a major factor responsible for gel formation, but others think that electrostatic forces may be the most important factor.

Blood plasma proteins such as albumin and globulins are also good emulsifiers. Emulsification of fat in a sausage product by plasma and its capability to retain the fat during heating of the sausage are extremely useful. Normal variations in salt concentration and the pH of sausage products have little effect on the emulsifying capacity. When compared to other additives, casein is a better emulsifying agent than blood plasma, but blood plasma is better than soy and meat proteins.

When blood plasma is used in meat sausage products it will decrease shrinkage and increase yield (approximately 4–5%), and the texture of the finished product will become more rigid due to the gelling properties of the plasma. If higher concentrations are used (usually no more than 2% plasma protein is used) the effect on sausages may be a slightly rubbery meat product. In addition to being added directly to a meat mixture, blood plasma can also be incorporated into a brine used for pumping a curing mixture into solid meat items. Up to 50% of the water in the curing mixture can be replaced with a brine containing 4% blood plasma protein (R. Strange, personal communication).

Use of blood plasma in bakery products has also shown promise. Blood plasma has good foaming (equivalent to egg albumin) and leavening properties and spray-dried plasma has been used successfully as an egg substitute. The foaming ability of blood plasma can be enhanced if the blood plasma proteins are precipitated by sodium hexametaphosphate $(NaPO_3)_x$ at a pH of 4.4 and resolubilized at a pH of 6.5 (R. Strange, personal communication). Blood plasma at the rate of 2–6% has been successfully substituted for bread flour in bread baking and this addition gave a significantly higher loaf volume. Increased levels of plasma darkened the crust and made the texture more open and coarse, but 2% plasma seemed acceptable from an odour and taste standpoint. The addition of plasma also increases the protein quality. With as little as 2% plasma protein powder added, the bread would contain 15% more protein and approximately 75% more lysine than was present prior to the plasma addition.

Angel-food cakes can also be supplemented with various quantities of blood plasma and the ratio of 30% plasma and 70% egg white has given an acceptable flavour (R. Strange, personal communication).

Blood plasma has also been spun into an acceptable meat analogue. This textured plasma protein is produced by adding NaOH to the plasma, adjusting the viscosity and extruding the spinning dope into a coagulating bath of acid and/or salt.

Utilization of haemoglobin

When blood plasma is separated from the erythrocytes, the major portion (60–70%) of the protein content remains in the haemoglobin of the erythrocyte fraction. This haemoglobin fraction gives an undesirable dark red colour when added to most foods in concentrations in excess of 1%. Haemoglobin is also often considered a very good catalyst for oxidation of unsaturated fatty acids; however, at high concentrations, haemoglobin appears to have an inhibitory effect on fat oxidation. The main use of haemoglobin, because of its colour, is confined to products in which the dark colour is traditional, such as black sausage, black pudding, blood breads and blood cookies. Demand for this type of product, however, is extremely limited and only a very small percentage of the available haemoglobin can be used by this route.

To reduce the dark colour characteristics, it has been known for a number of years that haemoglobin can be lightened by bleaching with a solution of hydrogen peroxide (H_2O_2). This procedure starts with haemolysis of the erthrocytes by the addition of 7 volumes of water to the erythrocyte fraction and by heating this solution to 70°C (158°F). A 3% hydrogen peroxide solution is then added, which oxidizes the haemoglobin to almost colourless verdomethaemoglobin. After the reaction is completed, the temperature of the erythrocyte fraction is reduced to 30°C (86°F) and the surplus hydrogen peroxide is removed with a catalase enzyme; the de-coloured protein coagulates into small spheres of approximately 1–2 mm in diameter which can be collected by filtering. The resulting material is bland in taste and insoluble in water; therefore, when added to a meat sausage item it behaves as an inert ingredient, causes the sausage to become softer and changes the sausage from a pink to a reddish brown or yellowish brown colour if added in concentrations of 10%. If added at levels of 1–1½% the flavour and taste of the sausage is only slightly affected.

Another alternative to oxidation is an attempt to remove the haem group from the haemoglobin. This is accomplished by adjusting the pH to 2, which causes the

organic chain to open and release the haem group. If a solution which contains ketones or alcohols in high concentrations is added, the haem group will remain in solution and the globin chain will precipitate due to the denaturation of the molecule. Ketones are usually more effective than alcohols for this reaction. If the globin is precipitated at low temperatures, the globin can be resolubilized in water and is almost completely free of haem.

In contrast to blood plasma, the globin fraction does not form a gel on heating. However, it swells after heating, has good capacity to bind water, has greater foaming capacity than plasma and is relatively stable against variations in pH and salt level. The swelling gives a creamy consistency to the product when a 10% globin dispersion is heated to 80°C (176°F). The main function of globin, if added to meat items, is the water-binding property related to the swelling. Globins also have good emulsion stability at pH 5, but almost none at pH 7. Globins also have superior foam-forming properties.

The removal of the haem group, however, greatly reduces the stability of the globin protein molecule and consequently the protein is much more sensitive to denaturing agents and heat. The solubility of the globin is reduced in the pH range of 6–9 and this is particularly important in a weak salt solution, as would be found in meat sausage items. A serious problem with acetone(C_3H_6O)-isolated globin (the acetone removes the colour) is an off flavour component adhering to the protein molecule. One such procedure for acetone removal of haem is outlined in Fig. 9.2. From a nutritional point of view, the removal or bleaching of the haem group also gives a less satisfactory product. This lowers the biological values and net protein utilization values and this seems to be more severe with the bleached than with the haem-removed haemoglobin procedure.

Digestion of haemoglobin with proteolytic enzymes is an alternative method for avoiding the dark pigmentation. One such procedure is outlined in Figure 9.3. The liberated amino acids and low molecular-weight peptides may have separated from the haem group and then can be incorporated into meat items. Another procedure to accomplish haemolysis of the erythrocytes is by dilution with water to a protein concentration of approximately 4% and adjusting the pH to 11 with 5 N sodium hydroxide (NaOH) (R. Strange, personal communication). After approximately 2 hours at 20°C (68°F) the protein is then suitable for hydrolysis which takes place in a membrane reactor. The enzyme reaction is accomplished and ultrafiltration is usally conducted with membranes that have cut off values of 50 000, 10 000 and 7000.

Alkalase is the enzyme normally used for enzyme digestion of the haemoglobin and hydrolysis takes place at 50°C (122°F) with a pH of 9. Yields of 72–73% of the protein cut-off values were used and the ultrafiltrate contains 0.1–0.2% haemin. The colour of the dry product depend on the acid used to neutralize the albumin hydrolysate, and the products have a fairly high content of ash and are somewhat bitter.

Another technique for obtaining a light-coloured, bitter, aromatic solution containing 7% protein via partial enzymic hydrolysis of erythrocytes involves a haemolysis of erythrocytes by the addition of 2 volumes of water, adjusting the pH to 3.9–4.0 by the addition of 1 N hydrochloric acid (HCl) and then fermenting for 12 hours at 50°C (122°F). The enzyme used is acid yeast proteinase. After fermentation, the pH is adjusted to 4.9–5 and the product is separated by centrifugation into a pale

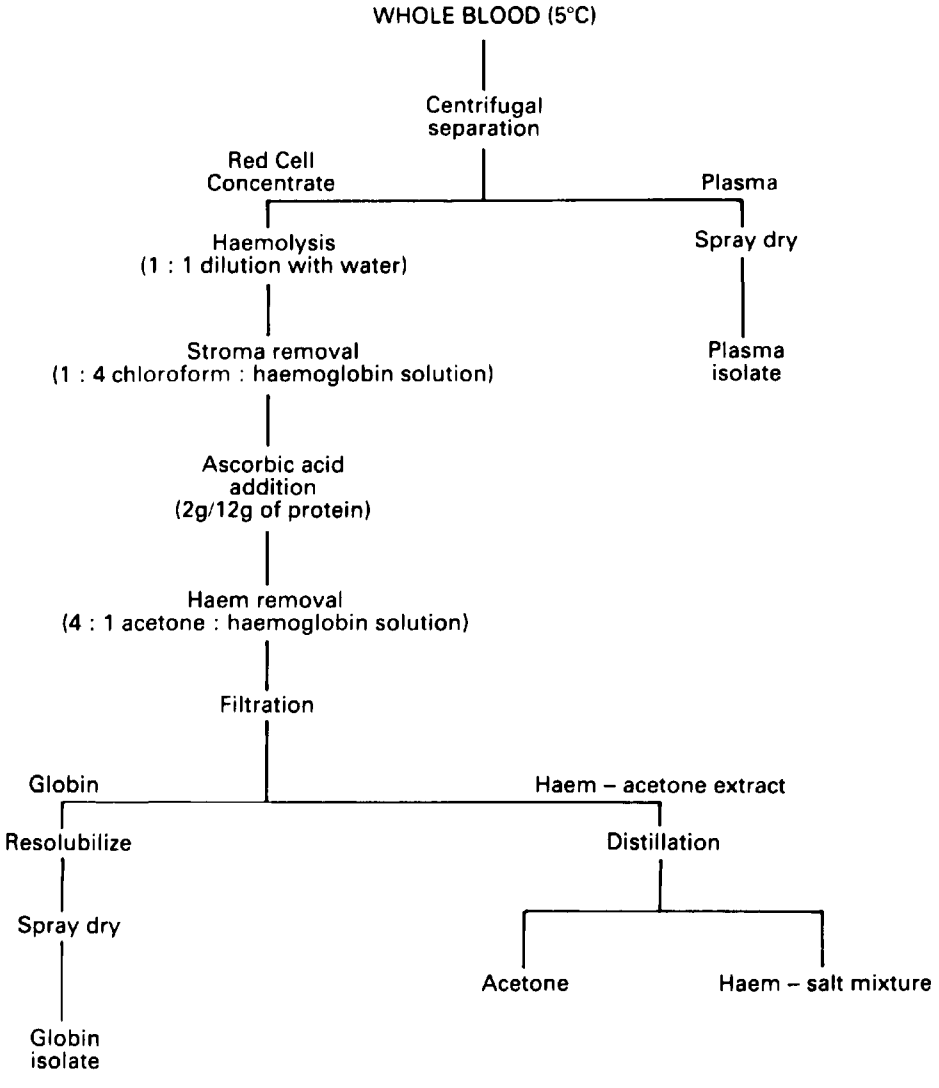


Fig. 9.2 — Flow diagram of the process for preparing globin by removal of haem. From Taybor *et* l. (1975), Dill (1975, 1976).

yellow supernatant with 8% protein and a brown precipitate containing 12% protein (R. Strange, personal communication). The protein in the supernatant corresponds to 55% of the protein in the erythrocytes and is reported to have a pleasant taste.

Bitter taste can often be removed from enzyme-hydrolyzed erythrocytes by treatment with strong acids such as hydrochloric (HCl) and then treatment with activated carbon or by deodorizing with steam. The nutritive value of the hydrolysed products will be considerably reduced as a result of tryptophan destruction and the ash content will normally be high.

An attempt to reduce the colour of haemoglobin might also involve treatment with calcium chloride ($CaCl_2$), and an ultrasonic treatment in a hydrodynamic vibrator or a valve homogenizer has also been used to change the properties of the erythrocyte material.

Attempts to disguise the colour by reducing its intensity have been made by

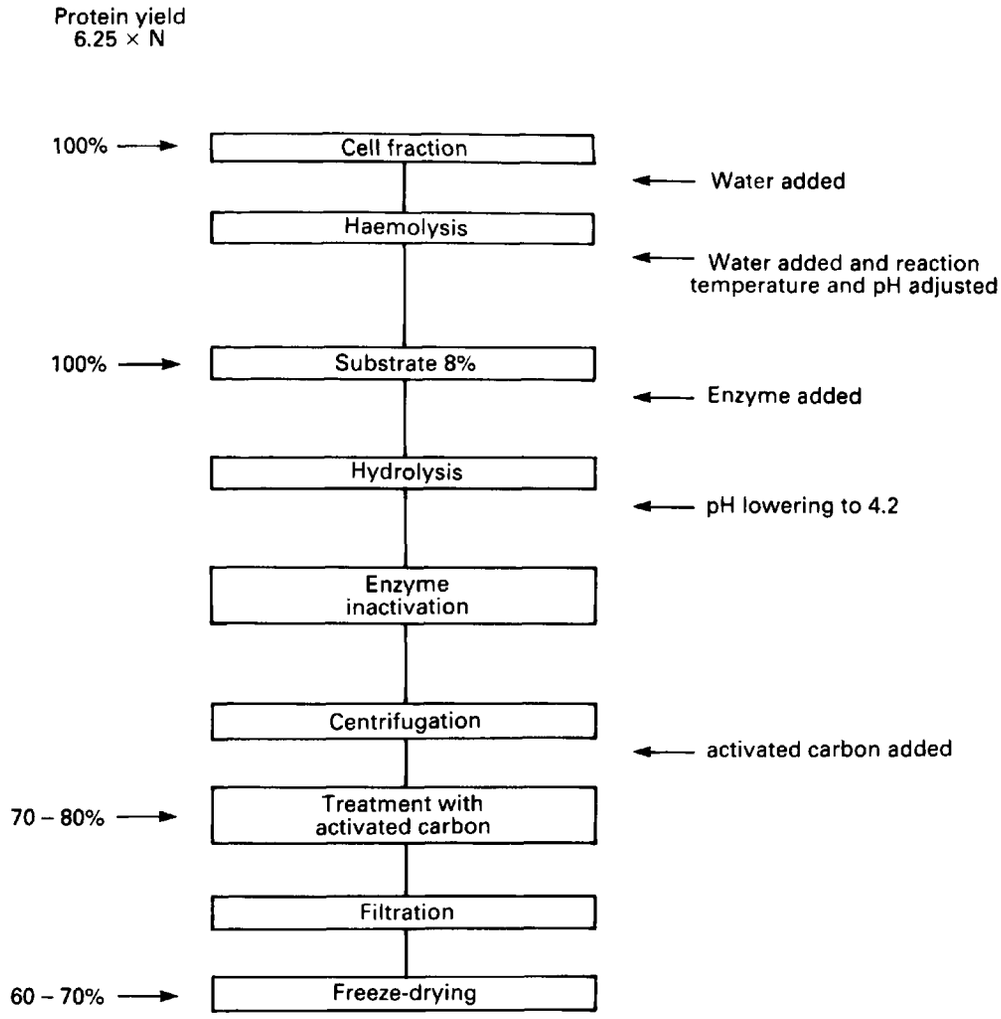


Fig. 9.3 — Flow-sheet of a process for enzymatic hydrolysis of haemoglobin involving treatment with activated carbon to remove haemin. From: R. D. Strange (personal communication).

mixing blood with skim milk and then precipitating the proteins. This 70–75% moisture product has been used at the 15% level in sausage products. Another approach to lightening the colour is to emulsify blood with fat and the treatment of blood containing fat emulsions with an homogenizer (150–350 kg/cm^2 (3133–4978 psi)) again reduces colour intensity. This product has been satisfactorily used at the 10% blood level in sausages.

Blood can be tested with acidified acetone (C_6H_6O) which will precipitate the haemoglobin and produce a white powder. However, this method is very tedious and expensive and may not be suitable for large-scale production.

In a few cases, the bright red colour has been used as a desirable characteristic and blood used in minute concentrations as a colour additive in meat products. This is particularly useful in countries where red dyes are not permitted to be used as a pigment. The haemogloblin is often preserved by the addition of sugars to give a water activity value in the area of 0.82–0.83. The pigment additive may have the composition of 45.6% haemoglobin dry matter, 38.7% corn syrup solids, 6.8%

dextrose monohydrate, 2.5% salt and 6.4% propylene glycol (R. Strange, personal communication). This mixture has to be stored below 4°C (39°F) to retard bacterial growth until it is used. It is normally used at a concentration of 5–20 g/kg of final product (0.5–2%).

BLOOD SERUM FOR LABORATORY USE

Blood serum (Divakaran, 1982) is fibrin-free blood plasma that is obtained after blood coagulation (also see Chapter 7). It is usually obtained in the sterile form for laboratory use. It may be obtained by sterile bleeding of animals during slaughter or from animals specially kept for blood production. In either case it must be handled very carefully to avoid contamination. After collection, blood is chilled and clotted; the clotted blood is cut into cubes to increase the surface area and to accelerate the separation of the serum. The serum that collects in the first 2–3 hours is rejected because of colour but the subsequent 12-hour collection is clear except for a few suspended red blood cells. It is then centrifuged (200–250*g*) for 30–40 minutes. The serum is then deactivated by heating for 30 minutes at 55±1°C (131±2°F) and is then sterilized by filtering. The sterilized serum is then stored under refrigeration, frozen or freeze-dried. Serum is used in the laboratory as a standard solution to inactivate proteolytic enzymes, as a medium in virus propagation, in production of virus vaccines and in bacteriological media. For other serum uses in the medical area see Chapter 7.

BLOOD ALBUMIN

Blood albumin (called dried blood serum in commerce) or dried blood plasma may be used as a substitute for dried egg albumin in food, to provide a gloss to leather finishes, as a lithographic coating solution, as an adhesive, in textile dyeing and as a stabilizer in feeds.

Blood is collected at slaughter without the addition of lime and the clotted blood is chilled. It is placed in perforated trays (20 mesh) and cut with a sharp blade into 1–2 cm (0.5–1 in) cubes. The serum is allowed to drain from the blood at 10°C (50°F). The first fraction is collected for 2 hours and is highly coloured, the second fraction is collected for 12–14 hours and contains suspended blood cells and the third fraction is slightly coloured. The serum is allowed to settle for 8–12 hours and the clear yellow serum is siphoned off. If room-temperature collection is used the collected serum is centrifuged at 250–300*g* for 30–45 minutes. A 0.5% phenol (C_6H_6O, carbolic acid) solution based on the weight of the serum is added as a preservative. The yield of serum using this technique is approximately 10–20% of the whole blood. The dried blood plasma is processsed by spray-drying or vacuum-drying and drum-drying to a powder. All drying should be conducted at less than 60°C (140°F) to prevent denaturation. Vacuum drying is usually at 25 mm of mercury and at 50–55°C (122–131°F) until the volume is reduced to approximately one-fifth and then the plasma is drum-dried at 60°C (140°F). It can also be vacuum-drum dried at 70°C (158°F). Blood albumin will yield approximately 20% of the weight of blood plasma or 1–2% of the weight of whole blood.

Blood albumin can also be produced from liquid blood that contains an anticoa-

gulant. This will result in a 4–5% increase in yield based on the weight of blood and, if prepared correctly, will improve quality. After collecting and adding the anticoagulant, the blood is stored under refrigeration for 10–12 hours allowing the suspended cells to settle (or the product is centrifuged at 250–300*g* for 30–45 minutes) and the supernatant liquid plasma is siphoned off. A warm calcium chloride ($CaCl_2$) solution (20%) is stirred into the plasma to give a 1% concentration. In 3–30 minutes the plasma will gel and this gel is cut and pressed through a filter cloth to obtain the serum. The serum and jellied plasma are centrifuged separately (1000–1500*g*) for 60 minutes to release the serum. To the serum is added 0.05% phenol (C_6H_6O) and the product is dried in the normal manner.

Good quality blood albumin is straw coloured, soluble in warm water and coagulates at 70°C (158°F). It contains 80% protein, 5% moisture and 15% salts. It should be stored in a cool place in air-tight containers.

RED BLOOD CELL PASTE

Red blood cell paste or corpuscle paste or plasma-free red blood cells are the raw material for manufacture of haemin or amino acids (Divakaran, 1982).

Collected blood with anticoagulants is centrifuged at 250*g* for 45 minutes and the supernatant plasma is siphoned off. The sedimented blood cells are diluted to four times their volume with 1% sodium chloride (NaCl) and recentrifuged. This washing process is repeated several times to remove the plasma. The packed cells are then vacuum evaporated (25–30°C, 77–86°F) to two-thirds of their original volume to produce red blood cell paste.

Another process dilutes (3 to 4 volumes) the blood containing anticoagulants with a solution of 1% sodium chloride (NaCl) and 5% glucose ($C_6H_{12}O_6$). It is cooled and the red blood cells form a sediment. The plasma is removed and the process is repeated. Finally the sediment is centrifuged (250*g*) for 45 minutes and then vacuum evaporated 25–30°C (77–86°F) to two-thirds of its original volume.

Red blood cell paste can also be obtained from red cells after separation of plasma for production of blood albumin.

The red blood cells paste is next sterilized by inspissation, which involves heating at 58–60°C (136–140°F) (this kills vegetative cells) for 30 minutes followed by overnight incubation at 37°C (99°F; encourages germination of spores whose vegetative cells are subsequently killed by 58–60°C heating) and then reheating. This process is repeated until the paste is negative for bacterial growth.

The product is vacuum-dried (10% moisture) at temperatures not exceeding 60°C (140°F). The yield is 25–30% by weight of whole blood.

The red blood cell paste is the raw material for isolation of leucine, lysine, histidine, phenylalanine, haemin and sphingomyelin.

SPRAY-DRIED BLOOD

Spray-dried blood, also called dark blood albumin or blood powder is a water-soluble dark reddish brown powder containing 5–8% moisture and 10–15% ash (Divakaran, 1982). It may be made from blood containing an anticoagulant, but this lowers the adhesive properties of the final product, defibrinated (removal of

insoluble protein formed during clotting of blood) blood makes a superior product. Spray-drying is acomplished with an inlet temperature of 200–250°C (392–482°F) and an outlet temperature of less than 70°C (158°F).

Soluble blood powder is manufactured by drying (8–10% moisture) at low temperature. Liquid blood is mixed with 0.05% phenol (C_6H_6O), placed in shallow pans (maximum depth of 1 cm (0.4 in) and forced-air dried at 55–60°C (131–140°F) or vacuum-dried at temperatures up to 70°C (158°F) after blood has lost 60% of its moisture.

These products can be used as adhesives, for clarification of liquids, for stabilizers in asphalt emulsions and in ceramics.

BLOOD MEAL

Blood meal is a dark brown, dry (5–8% moisture) granular product produced by drying whole blood or the heavy component removed during recovery of blood plasma or serum. The yield of blood meal from whole blood is approximately 20%. Often blood is run through a decanter to separate the coagulated blood into pre-dewatered blood meal and blood water which is released during coagulation. The blood meal is then cooked in a double boiler (or jacket) or by direct steam injection with stirring to avoid clumping. It can also be cooked in a vat over an open flame with constant stirring. Lime (70% calcium oxide, CaO) is sometimes added at the 0.5–1.5% level to increase storage life and to decrease the odour released during drying. Blood mixed with lime has a rubbery consistency and can be stored at 20°C (68°F) for 24 hours without spoilage. It contains 15–20% solids and is 80–85% moisture. The dark brown cooked product (crumbly consistency) is pressed to remove moisture and sun-dried or baked (with or without forced air circulation) at 60°C (140°F) to the desired moisture level. The dry-rendering process can also be used to dry the product. The dried product is then ground and used as feed (80% protein) or fertilizer (12% nitrogen, 0.22% phosphorus and trace elements). It is usually mixed with super phosphates to make a compounded fertilizer. If calcium is used in the production, this will also help to control the pH of acidic soils. Spray-dried blood can also be used as an adhesive, in asphalt emulsions, in insecticides, in ceramics and as a substitute for egg albumin when colour is not important. The dried product is often heated to 100°C (212°F) for 30 minutes, cooled and stored in air-tight containers to increase storage life.

Newer techniques to save the energy required for evaporation use a dewatering technique prior to drying the blood (Alfa-Laval, undated; Westfalia Separator, undated). The strained blood is preheated (55–58°C (131–136°F) in a storage tank and pumped to a coagulator (with live steam) where complete coagulation of blood proteins occurs. The coagulated blood is then fed to a conocylindrical rotor containing an axial screw conveyor. This decanter centrifuge removes 75% of the water. The fine crumb dewatered blood protein then goes to a cooker dryer for final drying (see Fig. 9.4).

The drying is often carried out in a rotating drum cooker heated by steam at 5.62 kg/cm^2 (80 psi) or in a dryer containing parallel discs mounted on a central shaft and scraper bars placed between the discs.

As previously suggested, high temperatures and/or extended periods of time used

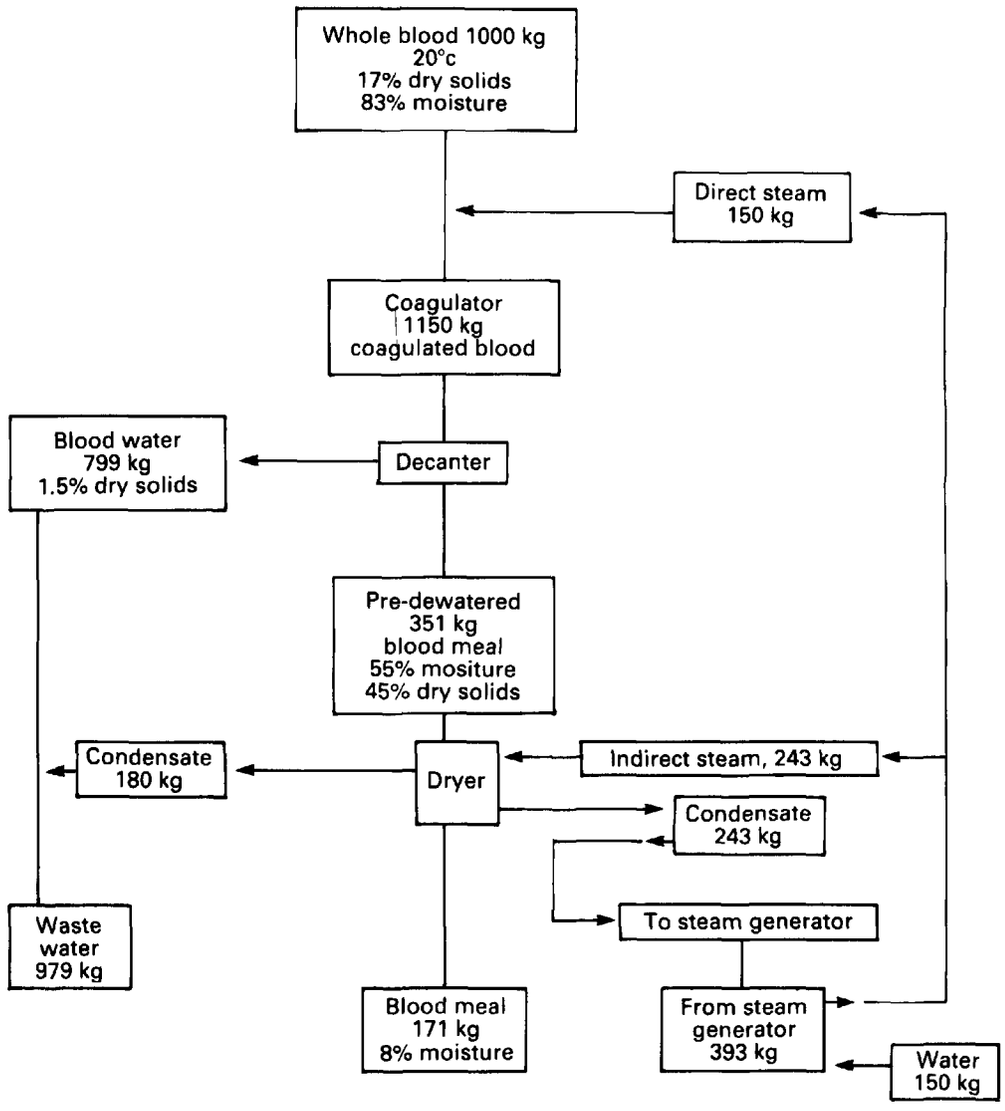


Fig. 9.4 — Blood-meal production using mechanical pre-dewatering. From: Westfalia Separator (undated).

in drying lower the nutritional value of blood meals. Ring drying has been reported (Waibel, 1974) to reduce this destruction and a comparison of ring and vat drying can be found in Table 9.5. For descriptions on ring and vat driers see Chapter 3.

Reduction in protein loss drying has been reported by fluidized bed drying (dried blood granules suspended in a hot airstream). Liquid blood is atomized into the side of the bed. A modification of this method of drying is to homogenize the blood, concentrate it to 25–30% solids by ultra-filtration and then dry it in a slatted bed drier containing polypropylene beads providing a large surface area for drying. The beads are coated with atomized blood and are kept in motion with high-velocity hot air. As the blood coat on the surface flakes off it is carried away by the airstream and a cyclone is used to separate and collect the dried blood. Blood dried by this method is approximately 90% soluble in water.

Table 9.5 — Comparison of blood meal dried in a ring or vat dryer

	Vat	Ring
Protein (%)	82.1	89.6
Lysine (%)	7.0	8.5
Available lysine		
Chemically (% of total)	80.4	86.5
Biologically (% of total)	49.0	83.0

Source: Waibel (1974).

Blood meal made with added lime (CaO) stores well, but that processed without lime cannot be stored for more than one month. Blood meal is used in calf starter rations, swine and poultry feeds. It is less digestible than meat meal. See Table 9.6 for compositional information.

FEEDING OF WHOLE BLOOD

Stabilization of whole blood by chemical preservation is possible and described by Akers (1973). Use of 1% urea (CH_4N_2O), 0.5% ammonia (NH_3) or — most effectively — 1% metabisulphite ($Na_2S_2O_5$) as a preservative has proven useful. Also blood without an anticoagulant can be stirred to keep it liquid, 1% sodium metabisulphite added and then mixed with a 20% solution of hydrochloric acid (HCl) to obtain a pH of 3.2 ± 0.3 which will stabilize it. The preserved blood can be held without refrigeration and can be fed at the rate of 0.3 kg (0.07 lb)/pig/day. This technique has not been used for human food, but certainly should be investigated.

Liquid blood can also be processed into a dry product by boiling for 5–10 minutes (with or without the addition of lime), mixing the blood with dry rice bran, wheat bran, finely chopped straw or dried stomach contents. The product is then air- or oven-dried and used as a stock feed supplement.

PICKLED OR ACIDIFIED BLOOD

Blood may be preserved by pickling with 3% commercial sulphuric acid (H_2SO_4) and this prevents the rapid onset of putrefactive changes. The pickled product may be used in terrestrial or aquatic animal diets (Divakaran and Sawa, 1986). The pickled blood may also be sun-dried to produce blood meal that has a high lysine value (Divakaran, 1987).

CO-PROCESSING OF BLOOD AND PAUNCH MANURE

Since blood is high in protein, particularly lysine, and paunch manure is rich in vitamins, contains some minerals and provides fibre, it would appear that the mixture from ruminants might make a well-balanced animal feed and also solve two disposal problems. The dried product will contain 40% true protein, 5% fat and 12%

Table 9.6 — Blood meal composition

Moisture	8–12%
Protein	75–83%
Arginine	3.6%
Glutamic acid	4.5%
Histidine	5.0%
Lysine	6.3%
Leucine	14.1%
Isoleucine	0.3–0.9%
Methionine	1.2%
Cystine	1.5%
Phenylalanine	5.9%
Threonine	3.8%
Tryptophan	1.1%
Tyrosine	2.3–2.8%
Valine	8.2%
Glycine	4.2%
Fat	1.2–1.6%
Crude fibre	0.8%
Ash	3.8–5.6%[a]
Calcium	0.3–0.4%[a]
Iron	0.4%
Magnesium	0.2%
Phosphorus	0.2%
Sulphur	0.4%
Manganese	5.3%
Copper	9.9 mg/kg
Sugar	0.4%
N-free Extract	2.6%
Vitamins	
Niacin	31.5 mg/kg
Pantothenic acid	1.1 mg/kg
Riboflavin	1.5 mg/kg

[a] Higher if processed with lime.
Sources: Divakaran *et al.* (1978), Divakaran (1982).

moisture (Walker, 1979). This co-dried blood and paunch manure has been satisfactorily fed to chickens and pigs as a partial replacement for meat meal and/or soya meal.

BLOOD CHAR

Blood char or blood charcoal is the carbon components of whole blood or blood meal produced by treating 20% of the weight of whole blood or 50% of weight of blood

meal with activating agents (e.g. zinc chloride ($ZnCl_2$), potassium sulphide (K_2SO_3), potassium thiocyanate (KCNS), phosphoric acid (H_3PO_4), sulphuric acid (H_2SO_4), hydroxides and carbonates of alkali metals, magnesium chloride ($MgCl_2$), calcium chloride ($CaCl_2$), steam (H_2O), carbon dioxide (CO_2), potassium carbonate (K_2CO_3) or sodium carbonate (Na_2CO_3)) and heating in air-tight containers to 650–750°C (1202–1382°F) in an oven for 6–8 hours. Blood char contains 80% carbon and is used for the absorption of gases, as an industrial decolourant and as an antidote for chemical poisoning.

Five metric tonnes (11023 lb) of whole blood or 1 tonne (2205 lb) of blood meal will yield 300–400 kg (661–882 pounds) of blood charcoal which contains 80% carbon (Divakaran, 1982). Fig. 9.5 illustrates a flow chart for char production.

BLOOD FOAM COMPOUNDS

Foam compounds are used in fire fighting and they function by protecting the surface from heat, retarding the formation of vapours, cooling the water in which the foam is carried and limiting the supply of oxygen to the fire. They are particularly useful in extinguishing fires of flammable liquids, such as hydrocarbons like gasoline, oils, paints, fats and naphtha (low boiling fractions of petroleum).

Blood foam compounds may be made (Divakaran, 1982) from animal blood, dried blood and blood meal by soaking the coagulated blood with 20 g sodium hydroxide (NaOH)/l (2% of blood) of blood (10% alkali on dry weight of blood basis). It is then heated with stirring in a steam-jacketed kettle at 90–95°C (194–203°F) for 4–5 hours. This hydrolyses the blood to the proteinases and peptones stage. The mixture is then neutralized to a pH of 6.8 with hydrochloric acid (HCl). The hydrolysed–neutralized blood is then concentrated to a specific gravity of 1.2 by heating at 60–70°C (140–158°F) and then 2.5% (w/v) ferrous sulphate ($FeSO_4$) is added as a stabilizer and 0.2–0.5 (v/v) cresol (C_7H_8O) is added as a preservative. The foam compound can then be stored in the liquid form or spray-dried. Foam (four times its volume) is generated by mixing the foam compounds with water and air under pressure.

NUTRITIONAL ASPECTS

Blood is a good source of most amino acids and the values in Table 9.7 are often used for whole beef blood.

When these values are compared with human requirements, blood is deficient in isoleucine and low in methionine and it should be mixed with proteins which can supplement these amino acids. Caseinate would be a good choice since this combination will have a high chemical score.

Blood is particularly rich in haem iron, which is biologically the most available form of iron.

PER (protein efficiency ratio) values of plasma, based on a casein values of 2.5, have been reported (Young *et al.*, 1973) as 2.8 and PER values for globin as −1.0. If globin is supplemented with 1.2%, DL-isoleucine the PER can be increased to 2.9 Haemoglobin is usually estimated as 150 mg/g (15%) of blood.

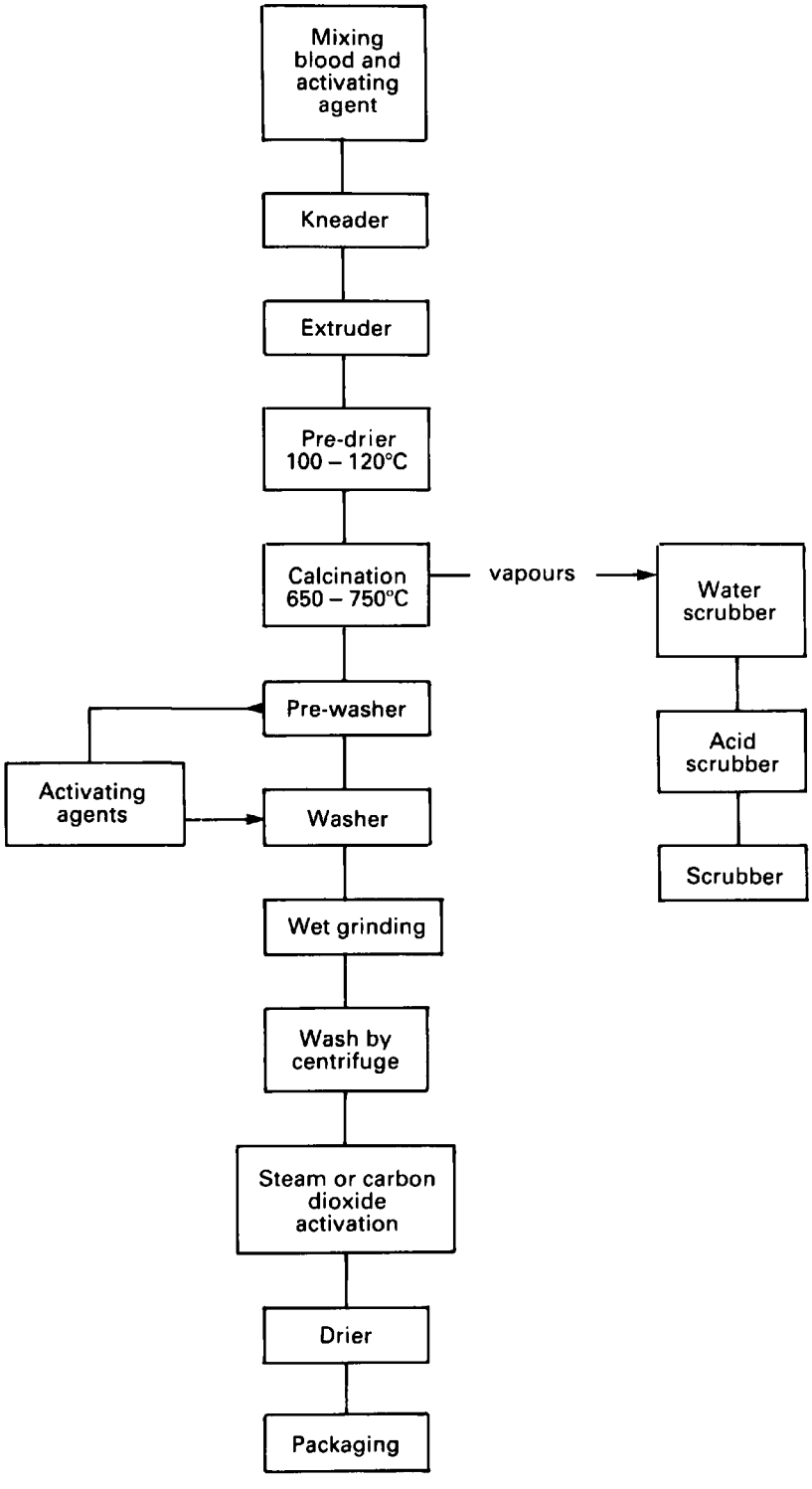


Fig. 9.5 — Blood char processing. From Divakaran (1982).

Table 9.7 — Amino acid contents of beef blood

	Whole beef blood (percentage of total protein)	Beef plasma (percentage of total protein)	Beef globin (percentage of total protein)
Isoleucine	0.4–0.9	1.0–3.4	0.2–0.3
Leucine	12.4–13.6	9.2–10.1	13.2–13.8
Lysine	9.2–9.7	6.5–9.2	9.8–10.5
Methionine	1.3–1.8	0.6–1.3	1.5–1.7
Phenylalanine	7.0–8.0	5.1–5.7	7.6–8.0
Threonine	4.7–5.2	2.6–7.1	3.8–4.1
Tryptophan	1.4	0.6–1.9	1.3–2.0
Valine	8.0–9.1	6.8–7.4	9.4–9.6
Histidine	5.6	3.0–3.5	6.6–7.8

REFERENCES

Akers, J. M. (1973) Utilization of blood. *Food manufacture.* April. pp. 31–32.

Alfa-Laval (undated), *Centriblood.* Denmark, Alfa-Laval.

Bengtsson, O. and Holmqvist, O. (1984) By-products from slaughtering. *Fleischwirtsch* **64**(3) 334.

Braathen, O. S. and Nilsen, J. A. (1982) Ideas for the use of animal blood plasma. *28th European Meeting of Meat Research Workers Congress*, Madrid.

Dill, C. M. (1975) Use of blood protein in processed meat and sausage. *National Provisioner.* Dec. pp. 14–17.

Dill, C. M. (1976), Plasma in edible meat products. *National Provisioner.* Aug. pp. 55–61.

Divakaran, S. (1980) *Animal blood.* National Information Center for Leather and Allied Industries, Series -2, Madras, India.

Divakaran, S. (1982) Animal blood processing and utilization. *FAO Agricultural Service Bulletin* **32** Rome, Food and Agricultural Organization of the United Nations.

Divakaran, S. (1987) An *in vitro* quality evaluation of slaughterhouse by-products preserved by pickling with sulphuric acid. *Biological Wastes* **19** 281–286.

Divakaran, S. and Sawa, T. R. (1986) Characteristics of slaughterhouse by-products preserved by pickling with inorganic acid. *Agriculture Wastes* **17** 67–75.

Divakaran, S., Scaria, K. J. and Santappa, M. (1978) Blood meal — its processing and utilization. *Leather Science* **25** 127–134.

Ellco Protein AB (undated), *Ellco's Processes*, Ellco Protein AB, Kavlinge, Sweden.

Filstrup, P. (1976) *Handbook for the meat by-product industry* Sweden, Alfa-Laval.

Kotula, A. W. and Helbacka, N. V. (1966) Blood volume of live chickens and influence of slaughter technique on blood loss. *Poultry Science* **45** 684–688.

Newell, G. W. and Shaffner, C. S. (1949) Blood volume determinations in chickens, *Poultry Science* **29** 78–87.

Quaglia, G. and Massacci, A. (1982) Proteolysates from slaughter-house blood. *J. Sci. Food Agric.* **33** 634–638.

Satterlee, L. D. (1975) *Improving utilization of animal by-products for human foods — a review. J. An. Sci.* **41** (2), 687–697.

Stevenson, T. R. (1979) Better uses for abattoir blood. *Agricultural Gazette* **90** (6) 42–45.

Stevenson, T. R. (undated) *Collection and processing of blood*, p. 76–77. Technical and Research Services, pp. 76–97. Caringbah, Australia.

Tabor, P. T., Dill, C. W. and Landmann (1975) Functional properties of proteins isolated from bovine blood by a continuous pilot plant process. *J. Food Sci.* **40** 155.

USDA (undated) Animal blood protein as a food ingredient. *Memorandum of Screening and Surveillance* Vol III, No 1, pp. 5–7.

Waibel, P. E. (1974) Processing and nutritional value of blood meals. *Meat Processing* **13** (5), pp. 102–103.

Walker, D. J. (1979) By-products processing. *Australian Meat Industry Bulletin*, Nov., pp. 58–60.

Westfalia, Separator (undated) *Separators, decanters and plants for processing animal blood.* Postfach, Oelde, West Germany.

Wismer-Pederson, J. (1979) *Utilization of animal blood in meat products. Food Technology* **33** 76–80.

Young, C. R., Lewis, R. W., Landmann, W. A. and Dill, C. W. (1973) Nutritive value of globin and plasma protein fraction from bovine blood. *Nutr. Rep. Intl.* **8** 211.

10

Pet or exotic animal food

In the United States, the pet population is increasing at a much faster rate than the human population and the 5738 billion dollar (1987) pet food industry is attempting to furnish a ration that is palatable and nutritionally balanced. The U.S. pet population in 1986 was 51.6 million dogs (38.7% of homes) and 56.3 million cats (29.4% of homes) which consumed approximately 9 278 000 pounds of food per year (Pet Food Institute, 1987). This same report states that there are 146 brands and 936 items in the dry dog-food category. Red meat plus horse, poultry, fish flesh, organs and by-products are used extensively in the manufacture of pet food, including that consumed by fur-bearing animals, especially mink. Such items as liver, intestines, kidney, udders, spleen, lung, meat meal, horse meat, condemned meat and cereal products are used in great quantities. Blood meal and meat meal are also used extensively in commercial fish-farming operations.

The more progressive and quality-conscious pet food manufacturers are using undenatured refrigerated or frozen meat and meat by-product items to manufacture their pet food. As many as 100 different items may make up this raw ingredient list. The frozen items would have an extended shelf life. The refrigerated items, often arriving in a ground state in an insulated rail tank car or truck, are normally manufactured into pet food within 3 days.

It is generally believed that cats prefer a diet based on fish (whole trash fish and fish waste) and that dogs like a meat-based diet, but there are many exceptions (European cat pet food is meat based) to this rule. In addition to the meat base, many pet food items add cereal grains (e.g. soybean meal and corn meal) to reduce the raw material cost and to improve consistency or body to the product (see Table 10.1).

QUANTITY OF PET FOOD REQUIRED

The amount of pet food a pet will consume depends upon its size, activity, general body metabolism and the environment. During normal maintenance metabolism, a medium-size dog requires 9.4–14.2 g (⅓–½ oz) of dry food or 28.4–42.5 g (1–1½ oz) of canned food per 0.45 kg (1 lb) of body weight per day. The average cat requires 70.9–99.2 g (2.5–3.5 oz) of dry food or 84 g (3 oz) of semi-moist food or 184 g (6.5 oz) of canned food per day.

Table 10.1 — Types of pet food

	Pet foods					
	Dry		Semimoist		Canned	
General						
Cost	low		mod–high		high	
Palatability	low		mod–high		high	
Moisture content	low (12% max)		mod–high (20–55%)		high (74–78%)	
Protein (min.%)	16		17		11	
Fat (min.%)	6		5		5	
Fibre (max.%)	5		2		1	
Ash (% typical)	7.5		6.5		3	
NFE or carbohydrate (% typical)	51.5		36.5		3	
Can be complete and balanced	yes		yes		yes	
Percentage of U.S. Market (1981) in dry matter equivalent	88		3		9	
Percentage of Japanese Market (1986) in dry matter equivalent	85		5		10	
Percentage (81%) of U.S. Market (1983) for dogs in dry matter equivalent	87		5		8	
Percentage (18%) of U.S. Market (1983) for cats in dry matter equivalent	68		10		22	
As is basis[a]	Dog	Cat	Dog	Cat	Dog	Cat
Production (1987) in U.S. (lb)	4552000	1059000	249000	180000	1698000	1276000
Protein (%)	21	31	21	25	12	14
Fat (%)	10	11	9	8	9	8
Carbohydrate (%)	48	38	30	28	1	1
Moisture (%)	8	8	30	30	75	75
Digestive Kcal/lb food[b]	1650	1700	1300	1300	600	600
Estimate food consumption for 50-lb dog, 10-lb cat (lb)[b]	1.06	0.18	1.35	0.23	2.92	0.5
Dry-matter basis						
Protein (%)	22.8	33.7	30	35.7	48.0	56
Fat (%)	10.9	12.0	12.9	17.1	36.0	20
Carbohydrate (%)	52.1	41.3	42.9	40.0	4	4
Moisture (%)	0	0	0	0	0	0
Digestible Kcal/lb food[b]	1805	1852	1851	2073	2415	1907

[a] Also see Table 10.5.
[b] 1 lb = 454 g.
Ralston Purina (1981), Pet Food Institute (1983, 1987), Kyodo Shiryo Co. (personal communication).

PROCESSING OF PET FOOD

The principles for producing canned pet foods are essentially the same as producing human canned food except the starting raw materials may be different (items may be used that are not declared fit by the inspection agency from an aesthetic standpoint for 'human consumption') but in both cases the ingredients should be fresh and

wholesome. The canning plants should be constructed of approved materials and should be kept clean at all times.

The general canning procedure includes coarse grinding of the flesh or by-products, pre-cooking in a continuous cooker with live steam, regrinding to a uniform consistency (or canned in chunk form), and mixing with other ingredients such as cereal grains, vitamins and/or minerals to produce a balanced or food-supplement diet. The total ingredients are then mixed in a blender and are filled into cans while the mixture is cold or hot. The cans are vacuum sealed and transferred to a retort for sterilizing. The retort may be a batch type or a continuous hydrostatic type. Temperature and time of cooking will depend upon steam pressure, size of can, can contents and rate of can movement. The cans are next rapidly cooled to approximately 38°C (100°F) and can drying takes place. The cans are next labelled and cased in corrugated cardboard boxes or shrink-wrapped (plastic wrap) in corrugated trays.

Dehydrated pet food is usually produced by blending animal-type meal products with cereal grains, vitamins and minerals. The dry mix is softened with steam and extruded into pellet shape. Due to its low moisture content, it is shelf stable.

Mink can also be fed fresh fish offal and in some areas as much as 70% of the mink's diet is fish. Processing fish for mink food requires fresh fish waste that is low in fat (less than 8%) and not of a species that has high levels (all fish have some) of thiaminase (an enzyme that destroys thiamin). Some fish-based foods need to have vitamin B_1 added. If whole fish are used, they are first washed, then used fresh or comminuted, placed in paper bags, frozen to −40°C (−40°F) and stored at −23 to −18°C (−10 to 0°F).

Fish entrails, fish offal, whole fish, poultry or mammal soft tissue can also be treated with urea for solubilizing and preserving the material at room temperature. This solubilized material can be readily mixed with other ingredients used in animal feed. The mixture can also be evaporated at 60°C (140°F) to concentrate it to 65% solids (still fluid consistency). Due to the low temperature of processing, the material retains much of its orginal nutritive value. If additional drying is desired, the urea is first fermented by yeast.

SUB DIVISION OF PET FOODS INTO CATEGORIES

Pet food manufacturers (Horn, 1975) categorize pet food into canned (subdivided into ultra-gourmet, gourmet and maintenance), non-canned (dry, semi-moist and soft–dry), and pet snack categories. These divisions may be described as follows:

Canned pet food

There are three general categories of canned pet food and they are the ultra-gourmet, gourmet and maintenance. The ultra-gourmet usually consists almost entirely of meat, tuna, fish, or manufactured meat, along with the necessary vitamins and minerals. The gourmet category involves a wide range of forms and the ground style is composed of ground meat and/or fish combined with gums, flours, vitamins and minerals. Some ground styles have manufactured meats or extruded meats added to give the product a chunky meat appearance at a lower manufacturing cost than the all-meat category. Another style of gourmet canned pet food involves using an extruded or formed meat shape mixed with a gravy. These forms can include

meatballs, dices or slices. Modern technology has allowed textured shapes that have a striking resemblance in texture to real meat. Other gourmet varieties add vegetables, manufactured cheese pieces, or manufactured egg pieces to the meat component. The third style is a maintenance formula. These formulas replace meat with grains such as ground corn, soybean meal, or barley. Enough meat or fish is added to allow a flavour claim to be made. Some companies add textured soy protein chunks to give a chunkier appearance.

Non-canned pet food

This area of manufactured pet food has recently undergone several evolutions, which have yielded a wide variety of shapes and sizes of dry and semi-moist pet foods. Recent developments have also yielded a combination of dry and semi-moist foods resulting in a soft–dry category. The traditional dry pet food comes in a variety of shapes. Extruded dry pellets and shapes are the most popular. Production and demand for the biscuit, meal and kibble categories is rapidly decreasing. The semi-moist category has recently seen a variety of imaginative shapes and styles. Semi-moist extruders are capable of producing burger strands, pellets, or marbled meat-appearance pieces. The mixing of the dry and semi-moist categories has produced the newly marketed soft–dry category. The dry and semi-moist pieces are specially formulated so that the difference in moistures stabilizes and equilbrates. This is necessary so that the lower moisture component does not draw the moisture from the higher moisture component.

Pet snacks

This area of pet food is small (2.9% by weight) but rapidly growing, both in the dog and cat specialties. Many different varieties have evolved from the basic dog biscuit. Premium dog biscuits, jerky snacks and sausage-shaped pieces are only a few of the many varieties in this rapidly developing segment of the pet food industry.

TYPES OF PET FOOD

Frequently pet foods are divided into types of dry, semimoist (In Europe: intermediate moisture) and canned and their corporation and market shares may be found in Table 10.1. These three types may be described as follows:

Dry type

Dry pet food makes up approximately four-fifths of the pet food market and has become much more popular with the advent of technology which makes it possible to gelatinize and expand this product with extrusion. This produces an exploded product that is light, popped and very palatable. Examples of dry pet food may be found in Tables 10.2 and 10.3. Dry types of pet food are low (10–12%) in moisture, contain from 5 to 12.5% fat, 20–35% protein, 35–50% carbohydrates (NFE, nitrogen-free extract), 2.9–4 digestible kcal/g (1300–1800 kcal/lb) and normally contain animal by-products (e.g. meat meal, meat and bone meal, meat by-products, and poultry by-products), fats and oils (e.g. animal fats), milk products (e.g. dried skimmed milk and dried whey), whole or dehulled cereal grains, cereal by-products, soybean products and mineral and vitamin supplements. The product is usually

Table 10.2 — Examples of four formulations for a dry dog-food diet

	Diet 1 (%)	Diet 2 (%)	Diet 3 (%)	Diet 4 (%)
Liver meal	—	1.0	—	—
Meat and bone soup	15.0	—	—	—
Meat and bone meal, 50%	—	—	10.0	10.0
Animal fat	2.5	6.0	10.0	9.3
Dried skim milk	5.0	—	—	—
Corn, kibbled	25.0	30.0	—	—
Corn, ground	—	—	47.8	43.7
Distiller's dried solubles	—	7.0	—	10.0
Oats, rolled	20.0	—	—	—
Wheat, flakes	25.0	28.0	—	—
Soybean meal, 49%	—	20.0	—	—
Soybean meal, 44%	—	—	26.9	21.7
Dehydrated alfalfa meal, 17%	—	2.0	—	—
Wheat germ meal	5.0	—	—	—
Dried brewer's yeast	1.0	2.5	—	—
Dicalcium phosphate	1.0	3.0	4.0	4.0
Salt	0.5	0.5	0.9	0.9
Vitamin A		5 million IU/ton		70,000 IU/kg
Vitamin D	1.5 million IU/ton		—	
Vitamin D_3	—		770 IU/kg	
Vitamin E	—		45 IU/kg	
Thiamin mononitrate	—		400 mg/kg	
Niacin	3 g/ton		11 mg/kg	
Riboflavin	3 g/ton		2 mg/kg	
Calcium pantothenate	10 g/ton		9 mg/kg	
Choline chloride	—		500 mg/kg	
Vitamin B_{12}	10 mg/ton		0.022 mg/kg	
$FeSO4.H_2O$	—		200 mg/kg	
MgO	—		500 mg/kg	
$Ca(IO_3)_2.6H_2O$			4.5 mg/kg	
$CuSO_4$			30 mg/kg	
ZnO	—		125 mg/kg	
$Na_2SeO_3.5H_2O$			0.35 mg/kg	
MnO_3	—		15 mg/kg	

From: Perry (1984), Corbin (1984).

heated sufficiently to partially dextrinize (convert into dextrin) the starch. It is manufactured in the form of meals, pellets, biscuits, kibbles (broken biscuits) or extruded (expanded) products. It may be fed either dry or moistened by the addition of water at feeding time.

Marbled dry pet food

Marbled dry pet food may be produced by blending ingredients, processing and cooking portions in an uneven manner and then mixing the uneven processed portion in a manner so that discrete boundaries separating the portions are discernible (Bone and Shannon, 1975). Other techniques require making two doughs, colouring them (e.g. red and white) and extruding these two doughs together (Bone and Shannon, 1977). A soft, dry pet food containing a polysaccharide in which white and red dough are mixed to give a marbling effect has also been developed (Bone, 1977). This product, when dried to 15% moisture, still has the texture and appearance of meat.

Table 10.3 — Percentage of time an ingredient is located on an ingredient list found in random sampling of pet food labels

	Canned		Semimoist		Dry	
	Dog	Cat	Dog	Cat	Dog	Cat
Number of labels examined	12	11	10	10	10	10
Percentage found						
Animal fat	8.3	9.1	50.0	80.0	100.0	100.0
Animal liver and glandular meal					10.0	20.0
Bacon	16.7					
Bacon fat			10.0			
Barley	8.3					
Beef	41.7	36.4	80.0	30.0		20.0
Beef and bone meal					40.0	
Beef by-products	25.0		70.0	10.0		
Beef digest					30.0	
Beef meal						10.0
Bone marrow	8.3					
Bone meal					10.0	
Brewer's dried yeast				90.0	20.0	60.0
Catfish		9.1				
Cheese					10.0	
Chicken	25.0	36.4	30.0	70.0		20.0
Chicken by-products						10.0
Chicken by-products meal						40.0
Chicken liver		9.1				
Chicken skin			30.0			
Colour	16.7	45.0	70.0	90.0	70.0	70.0
Condensed fish solubles				10.0		20.0
Corn flour			40.0	10.0		
Corn germ meal			20.0			
Corn gluten meal			30.0	100.0	50.0	90.0
Corn starch			10.0			
Corn syrup			100.0			
Cracked barley	8.3					
Digest of poultry by-products					30.0	30.0
Dried cheese powder			10.0		10.0	20.0
Dried cheese solids			30.0			
Dried liver digest					10.0	10.0
Dried milk powder						10.0
Dried potato products	8.3					
Dried skim milk			10.0			50.0
Dried tomato pomace					10.0	
Dried whey			40.0	90.0	20.0	70.0
Dried whole eggs		18.2				20.0
Dried yeast					10.0	40.0
Egg						10.0
Fish	8.3	27.3		30.0		
Fish and fish by-products						20.0
Fish and salmon flavours		9.1				
Fish meal						50.0
Food starch modified	25.0					
Giblets		9.1				
Ground corn					100.0	

Continued on next page

Table 10.3 — *continued*

Ground gluten meal					10.0	
Ground wheat					40.0	90.0
Ground yellow corn				90.0		90.0
Guar gum	8.3					
Herring meal						10.0
High fructose corn syrup			60.0			
Hydrolised vegetable protein					10.0	
Liver	16.7	63.6	10.0	20.0		20.0
Liver digest		45.5				
Mackerel		9.1		20.0		
Meat and bone meal	8.3				70.0	40.0
Meat by-products	25.0	72.7			10.0	10.0
Meat meal	8.3					
Mineral supplement	100.0	100.0	100.0	100.0	100.0	100.0
Poultry by-products	8.3	27.3			10.0	
Poultry by-product meal		9.1		100.0	30.0	60.0
Poultry parts	8.3					
Processed grain by-products	8.3					
Rice hulls			20.0			
Rice mill by-products					20.0	
Salmon				20.0		
Salmon meal						10.0
Sardine		9.1				
Shrimp meal						10.0
Sodium caseinate			10.0			
Soybean grits	8.3		70.0	10.0		
Soybean hull					10.0	
Soybean meal	25.0		40.0	90.0	80.0	100.0
Soybean mill feed						10.0
Soybean oil	16.7					
Soy flour	8.3		90.0			
Soy protein concentrate						10.0
Textured vegetable protein	8.3					
Tuna		18.2				
Tuna meal				10.0		50.0
Turkey	8.3	9.1				20.0
Turkey meal						10.0
Veal		9.1				
Vegetable gum		81.8			10.0	
Vegetable oil	16.7	18.2	40.0		10.0	
Vitamin supplement	100.0	100.0	100.0	100.0	100.0	100.0
Water	58.3	36.4	30.0	100.0		
Water sufficient for processing	33.3	63.6	50.0			
Wheat bran	8.3					
Wheat feed flour			30.0			
Wheat flour	16.7	27.3	20.0	100.0	20.0	
Wheat germ meal				80.0	20.0	60.0
Wheat meal run		27.3			10.0	
Wheat middling	8.3				20.0	
Wheat starch			10.0			
White fish		9.1				
Whole eggs		36.4				
Whole wheat					10.0	
Xanthan gum	8.3					
Yeast culture						10.0

Source: Kyodo Shiryo Co (1986, personal communication), Pet Food Labels, 1987.

Dry bone substitutes

Bone substitutes may be manufactured by making a slurry of animal by-products (e.g. bones, skins, lungs, livers, hearts, kidneys, heads and feet), adding a binder and then dehydrating the slurry. It can be formed and then dehydrated into a hard bone-like substitute in a variety of shapes or powdered for soft foods (Cagle, 1975). In some cases, a cross-section of a hollow bone is produced and a filling is added resembling bone marrow.

Dry pet food with a meat-like texture

To produce a meat like texture and appearance, pet food can be made by mixing substantial amounts of amylaceous ingredients (e.g. starch or starch-like material) with conventional dry food ingredients, with specific proteinaceous adhesives (e.g. collagen, albumens and casein), and with plasticizing agents (Balaz *et al.*, 1976). The product is then extruded.

Dry high-fat pet food

A dry expanded pet food can be produced with high levels of fat (25–30%) that does not have an external greasy surface (McCulloch and Nelson, 1977). This is accomplished by a homogenization step in the manufacturing process.

Soft-crumb dry pet food mixture

A soft-crumb dry product is produced by mixing farinaceous ingredients (high in starch or grain) with flavour ingredients (e.g. fish or meat scrap), hydrolysed protein, fibrous ingredients and plasticizing agents (Miller and Hansen, 1975). Fat and fat-transport material is then added and thoroughly mixed before the product is extruded.

Mixture of hard and soft dry foods

Soft dry foods are more palatable, but hard foods have desired teeth-cleaning properties. A mixture of the two has been developed (Bone and Shannon, 1977b) and consist of hard substantially amylaceous particles intermixed with soft, meat-like non-amylaceous particles.

Semimoist pet food

Semimoist pet food is manufactured to have the appearance of meat or meat products, is moderate (25–50%) in moisture, contains 16–25% protein, 3–10% fat, 25–35% carbohydrates and high-quality diets contain 2180 digestible kcal/kg (1300 kcal/lb). The semimoist foods are protected against spoilage without refrigeration with sucrose ($C_{12}H_{22}O_{11}$), propylene glycol ($C_8H_8O_2$) and sorbates. Other bacteriostats for semimoist pet food include potassium sorbate ($C_6H_7KO_2$), calcium sorbate ($C_{12}H_{14}CaO_4$), sorbic acid ($C_6H_8O_2$) and 3–9% polyhydric compounds (e.g. propylene glycol ($C_3H_8O_2$), 1,3-butanediol ($C_4H_{10}O_2$) with 3% acid (acetic, $C_2H_4O_2$). A carbon dioxide (CO_2) packaging atmosphere has been found to be helpful in controlling microbial growth. Semimoist pet foods normally contain animal products (e.g. meat and meat by-products), fats and oils (e.g. animal fat), milk products (e.g. cheese rind), soybean products, carboxymethyl cellulose, mineral and vitamin supplements. This product is usually manufactured in the shape

of patties or as simulated meat chunks. Semimoist pet food must be carefully packaged to maintain the quality and to protect it against spoilage. Semimoist foods are higher in palatability than dry diets and are easy to store if package integrity is maintained and easy to serve.

Marbled semimoist pet food

Semimoist food can also be extruded with two coloured mixes to give a final appearance of marbled product (Charter, 1973).

Liver flavour semimoist pet food

Liver flavour an be produced in pet food with liver or with blood and reducing sugar and is usually added at the 1–5% level to increase pet acceptance (Lugay and Beale, 1978).

Binders in semimoist pet food

Binder systems for semimoist pet food can come from different and uncommon sources such as sulphur-containing amino acids, lower alkyl mercaptans, lower alkyl sulphides and disulphides, thioacids, salts and thiamin (Stocker *et al.*, 1976). Gels can also be used to give the product texture and a gel or coagulated binder stabilized against bacterial growth by a pH below 5.5 has been used (Burrows *et al.* 1977). Typical binders, such as cereal flour, are often preferred but pregelatinized starch can also be used. Heat coagulated proteins, such as vital wheat gluten have been used, and after heating this product will form a solid product (Palmer *et al.*, 1975).

Egg-containing semimoist pet food

Semimoist pet foods containing egg and meat products have been developed (Burkwall; Reardanz and Boudreau, 1976) that with independent processing allow the final product to display a distinct egg portion appearance.

Pastry-shell filled semimoist pet food

A pet food has been developed with an inner, proteinaceous matrix surrounded by an outer pastry shell (Hildebolt, 1975). This provides the product with bacteriological stability even though the inner portion will support and has sufficient moisture (20–25%) for bacterial growth. Another technique (Bernotavicz, 1975) for manufacturing is a simultaneous extrusion of a centre-filled, pillow-shaped meat-containing (53% moisture) product which, because of the dry outer covering, is stable against microbiological growth.

Deep-fat frying of semimoist pet food

Frying of semimoist pet food in oil at 121–177°C (250–350°F) has also proven to give a crisp exterior and soft meaty interior that can be shelf stable (Clausen, 1977).

Canned pet food

Canned pet food is primarily animal by-products (e.g. bones, cheek meat, damaged carcass parts, intestines, liver, lungs and stomach tissue) from slaughtered animals

and from animals that have died but are salvaged before the tissue decomposes. Normally the skin, claws, horns and rumen content are removed before this tissue is processed. An example of the ingredients in canned pet food may be found in Tables 10.3 and 10.4. Canned pet food is high (74–80%) in moisture, contains 8–20%

Table 10.4 — Typical pet food list of ingredients

Canned
Fresh fish
Meat and meat products
Meat and meat by-products
Poultry and poultry by-products
Ground corn
Soy grits or flour
Cracked wheat
Cracked barley
Ground bone
Salt
Water sufficient for processing
Mineral mix sufficient to meet NRC requirements
Vitamin mix sufficient to meet NRC requirements
Additional ingredients in dry
Corn gluten feed
Meat and bone meal
Animal fat
Additional ingredients in semimoist
Soybean flakes, bran flakes
Soluble carbohydrates
Antimycotic and emulsifer
Propylene glycol
Dried skimmed milk

Source: Brady (1965), Alpo (1987), Carnation (1987), Subcommittee on Dog Nutrition (1985).

protein, 2–15% fat, 1–2 digestible kilocalories/g (400–1000 kcal/lb) and can be either nutritionally complete or incomplete and utilized as a food supplement. The nutritionally complete type may be either a dry-type pet food formula to which water has been added and the product canned, or may be a high-fat product containing animal products (e.g. meat and meat by-products), fats and oils, soybean products, mineral and vitamin supplements. The nutritionally incomplete food supplements may contain only animal products (e.g. meat and meat by-products) and therefore they will be low in calcium and sometimes are suboptimal in phosphorus. The canned diets are superior in palatability.

Gravy in canned pet food

Canned pet food products, such as meat in gravy, that remain pourable throughout their shelf life have been produced by adding sufficient acid (1–2% phosphoric (H_3PO_4) or 0.5–3.5% citric ($C_6H_8O_7$)) to lower the pH to 4.5 and to inhibit the gelling properties of collagen (Reesman, 1974).

Marbled canned pet food

Simulated marbled meat can be produced from a heterogeneous mixture of red and white meats that are extruded and divided into chunks (Riggs and Sarno, 1975) and then retorted.

Textured offal in canned pet food

To give offal the appearance of muscular tissue it may be passed through a texturing machine that places in the surface a series of incisions (Kern *et al.*, 1975) to make it visually resemble muscle tissue.

Colouring agent for mammary tissue used in canned pet food

The yellow or cream colour of the mammary gland restricts its use in pet food. This tissue can be coloured by injecting it with a solution of citrated blood and 200 ppm of sodium nitrite ($NaNO_2$) (Kotthoff, 1975).

Extruded animal flesh and bone used in canned pet food

The extrusion of animal flesh and bones under high pressure through a series of orificed plates gives a texture where the bones are indistinguishable from the remainder of the product (King, 1974).

Gelling agents

Gelling agents are used to maintain homogeneity during processing and to control moisture that is added. They include locust bean gum, carboxymethyl cellulose, guar gum, carrageenan and other starches and thickeners.

Frozen pet food

Frozen pet food is used only to a limited extent and is often made by combining meat trimmings with dry pet food. It is sometimes made into patties and then frozen.

An example of frozen pet-food processing (Anon, 1986) is the salvaging of tissue from animals that have died naturally. The hide is removed from the carcass and the tissue is evaluated for soundness for use in pet food. The carcass is then placed in 2°C (36°F) chill cooler. Next the muscles are removed by knife and the tissue is graded and ground. During grinding, granulated charcoal is added as a denaturing material. The material is next packed in wax-lined cartons and frozen in a −23°C (−10°F) blast freezer and sold frozen to dog owners. The partially deboned carcass next goes to a mechanical deboner which reclaims the remainder of the tissue. The deboned tissue is then placed in 22.7 kg (50 lb) trays, liquified denaturant is placed on top of the material and the product is blast frozen. It is then knocked out of the trays, placed on a skid and stretch wrapped and then shipped naked (no further protection) to a pet food manufacturer, who may produce wet, semi-dry or dry pet food.

PALATABILITY ENHANCERS

Since many pet mixtures may have an undesirable odour, flavour or texture, there is often a need to enhance the palatability in order to make it acceptable to the pet, and sometimes the odour needs to be enhanced so that the pet owner will feed this product to the pet. These enhancers are sometimes mixed with the food, but in many cases they are often coated on the external surface. Such things as yeast (e.g. *Ascomycete* or *Asporogene*), microorganisms cultured on hydrocarbons, protein and fat treated with lipase and protease, fish solubles, citric ($C_6H_8O_7$) and phosphoric (H_3PO_4) acid solution (for cat food), meat digests, amino acids, sweeteners such as fructose and sugar, and modified animal or plant fat extracts are often added to the pet food. Texture changes can also assist palatability and fine comminuting helps with some products. Fish scrap coating or precooked pieces of meat, poultry of of fish on the surface of a less palatable inner core are also sometimes used.

NUTRIENT REQUIREMENTS

If given the opportunity, dogs will normally consume food until their caloric requirements are met and then they will stop eating. In many cases however they will consume enough calories to become overweight. Cats need (Subcommittee on cat Nutrition, 1986) a daily food allowance of 78 g (dry), 83 g (semimoist) and 227 g (canned) food per kilogram of body weight for a 10-week-old kitten and 25 g (dry), 27 g (semimoist) and 73 g (canned) food per kilogram of body weight for a 40-week-old cat. Inactive, active, gestation and lactation requirements in cats utilize 22, 25, 31 and 78 g food/kg body weight of dry-type food, 23, 27, 33 and 83 g/kg body weight of semimoist-type food and 64, 73, 91, 227 g food/kg body weight for canned food respectively. An increase in animal size, cold weather, exercise, the last trimester of pregnancy and lactation all increase maintenance needs. Dogs are capable of utilizing large quantities of carbohydrates and an upper limit is often set at 65% (but up to 81% has been used satisfactorily) and acceptability and suitability is increased by cooking (Perry, 1984). Fats provide energy and essential fatty acids, are a carrier for fat-soluble vitamins, add palatability and improve the texture of pet food diets. The minimum fat level is often considered to be in the area of 5% and 1% lineoleic acid, which is necessary to maintain health of skin and hair. On a dry-matter basis, the minimum is often considered to be 10% fat and 1.5% linoleic acid. Levels up to 40% fat have been fed successfully to dogs (Perry, 1984). The protein level for growing dogs should be 22–25% (it should be raised if the fat content of the diet is high) and for maintenance of adult dogs should be 17%. The protein level for growing kittens is often listed as 24%. Nutrient requirements for dogs and cats can be found in Table 10.5 and the quantity of nutrients available in various forms of pet foods is given in Tables 10.1 and 10.5. Other references include a publication titled '*Nutrient Recommendation for Dogs*' by Jim Corbin (undated). The composition of meat, seafood and poultry by-products can be found in Tables 10.6 and 10.7.

PET FOOD LABELS

In the U.S., the Association of American Food Control Officials (AAFCO) establishes and enforces the label regulation for pet foods.

Table 10.5 — Nutrient requirements (and selected recommended allowances) for growing dogs and cats (percentage or amount per kilogram[a] of food)[b]

	Requirements		Quality of nutrients					
			Dog			Cat		
	Dog, dry basis	Cat, dry basis	Dry type	Semi-moist	Canned or wet	Dry type	Semi-moist	Canned or wet
Moisture level (%)	0	0	10	25	75	6–9	29	72–80
Dry moisture basis (%)	100	100	90	75	25	91–94	71	20–28
Protein (%)	22	24	20	16.5	5.5	33–35	25	9–11
Arginine (%)	0.50	1.0						
Histidine (%)	0.18	0.3						
Isoleucine (%)	0.36	0.5						
Leucine (%)	0.58	1.2						
Lysine (%)	0.51	0.8						
Methionine–cystine (%)	0.39	0.75						
Phenylalanine–tyrosine (%)	0.72	0.85						
Threonine (%)	0.47	0.7						
Tryptophan (%)	0.15	0.15						
Valine (%)	0.39	0.6						
Dispensable amino acids (%)	6.26	—						
Fat (%)	5	9	4.5	3.75	1.25	9–10	9.8	4–5
Linoleic acid (%)	1	1	0.9	0.75	0.25			
Arachidonic (%)	—	0.02						
Minerals						7–11	6.5	2–3
Calcium (%)	0.59	0.8	1.0	0.8	0.3			
Phosphorus (%)	0.44	0.6	0.8	0.7	0.22			
Potassium (%)	0.44	0.4	0.5	0.45	0.2			
Sodium (%)	0.06	0.05	0.4	0.3	0.12			
Chloride (%)	0.09	0.19	0.6	0.5	0.18			
Magnesium (%)	0.04	0.04	0.036	0.03	0.01			
Iron (mg)	31.9	80	54	45	15			
Copper (mg)	2.9	5	6.5	5.5	1.8			
Manganese (mg)	5.1	5	4.5	3.8	1.2			
Zinc[c]	35.6	50	45	38	12			
Iodine (mg)	0.59	0.35	1.39	1.16	0.39			
Selenium[c] (mg)	0.11	0.10	0.10	0.08	0.03			
Vitamins								
Vitamin A (IU)	3710[d]	3333	4500	3750	1250			
Vitamin D (IU)	404[e]	500	450	375	125			
Vitamin E (IU)	22[f]	30	45	37.5	12.5			
Thiamin (mg)	1.00	5.00	0.90	0.75	0.25			
Riboflavin (mg)	2.5	4.0	2.0	1.6	0.5			
Pantothenic acid (mg)	9.9	5.0	9.0	7.5	2.5			
Niacin (mg)	11.0	40.0	10.3	8.6	2.8			
Pyridoxine (mg)	1.1	4	0.9	0.75	0.25			
Folic acid (mg)	0.2	0.8	0.16	0.14	0.04			
Biotin[c] (mg)	0.10	0.07	0.09	0.075	0.025			
Vitamin B_{12}[c] (mg)	0.026	0.02	0.020	0.017	0.006			
Choline (mg)	1250	2400	1100	900	300			

[a] To obtain the amount per pound divide by 2.205. Blank spaces means data not reported.

[b] Based on diets with metabolizable energy concentrations in the range of 3.5–4.0 kcal/g of dry matter. If energy density exceeds this range, it may be necessary to increase nutrient concentrations proportionately. Recommended nutrient levels selected to meet the requirements of the most demanding segments, i.e. rapid growth and lactation.

[c] Recommended allowances based on research with other species.

[d] This amount of vitamin A corresponds to 1.5 mg of all *trans*-retinol per kilogram of dry diet (one IU of vitamin A activity equals 0.3 μg of all *trans*-retinol).

[e] This amount of vitamin D activity corresponds to 12.5 μg of cholecalciferol per kilogram of dry diet (one IU of vitamin D activity equals 0.025 μg of cholecalciferol).

[f] This amount of vitamin E activity corresponds to 50 mg of *dl*-alpha-tocopheryl acetate per kilogram of dry weight (one IU of vitamin E activity equals 1 mg of *dl*-alpha-tocopheryl acetate).

Source: National Academy of Sciences (1974, 1978), Perry (1984), Subcommittee on Dog Nutrition (1985), Subcommittee on cat Nutrition (1986).

Current regulations require that product name on the principal display panel and a flavour designation if used in the same type of lettering. If the product name includes a meat item, then there must be at least 10% of this meat item in the

Table 10.6 — Composition of raw meat by-products

	Percentage					
	Moisture	Protein	Fat	Fibre	Ash	Calcium
Cattle						
Lips, raw	70.0	18.0	6.9	—	—	—
Liver, raw	73.0	20.0	3.2	o	—	0.01
Lungs, raw	80.0	16.0	3.0	—	—	—
Spleen, raw	75.0	18.0	4.0	—	—	—
Udder, raw	75.0	12.0	12.0	—	—	—
Hogs						
Bone, raw	55.0	15.0	13.0	—	17.0	—
Cracklins	2.5	84.0	11.5	—	2.0	—
Defatted pork tissue	61.5	27.0	10.5	—	1.0	—
Kidney, raw	75.5	15.6	6.9	—	1.5	—
Liver, raw	71.0	20.0	4.6	—	1.5	—
Lungs, raw	78.5	13.6	6.7	—	1.0	—
Skin, raw	48.0	21.0	31.0	—	0.5	—
Spleen, raw	69.5	16.5	12.5	—	1.5	—
Horse						
Meat, raw	76.0	18.0	4.1	—	—	0.03
Meat with bone, raw	64.0	32.6	12.2	—	—	—

Source: National Academy of Sciences (1974), OSU (1987).

product. If the product name includes only a single meat item, then there must be at least 70% of this meat item in the pet food. If the product name contains several meat items, then there must be at least 70% of these total ingredients in the product and the quantity must be in the order listed in the name. The words 'dog food', 'cat food' or similar designation must appear on the principal display panel.

Current nutrient guarantees are required on the label and they include:

Minimum crude protein
Minimum crude fat
Maximum crude fibre
Maximum moisture

If the manufacturer desires to list additional guarantees, they will follow moisture.

All ingredients use in the manufacture must be listed in descending order by weight in the ingredient listing. The terms 'meat' and 'meat by-products' shall mean cattle, hogs (pigs), sheep or goats, and, if other species are used, they must be declared.

Table 10.7 — Composition of meat, seafood and poultry by-products

Composition	Meat meal	Meat and bone meal	Bone meal	Animal liver meal
Dry matter (%)	92–93	94–96	95–97	93
Dry basis				
Protein (%)	57–65	51–54	6–13	72
Fat (%)	8–11	10–12	3	16
Fibre (%)	2–3	2	2	1
Minerals				
Calcium (%)	6–8	10–11	25–31	0.5
Copper (%)	10–42	1.6	17	96
Iron (mg/kg)	0.05	0.05	0.09	0.07
Magnesium (%)	0.1–0.3	1.2	0.7	—
Manganese (mg/kg)	10–21	13	32	9
Phosphorus (%)	3–4	5	13–14	1
Potassium (%)	0.6	1.6	—	—
Sodium (%)	1.8	0.8	0.5	—
Zinc (mg/kg)	—	104	450	—
Vitamins				
Biotin (mg/kg)	0.1	0.1	—	0.02
Choline (mg/kg)	2000	2300	—	—
Folic acid (mg/kg)	0.05–1.6	0.05	—	6
Niacin (mg/kg)	43–61	51	4	220
Pantothenic acid (mg/kg)	3–5	4	2.5	49
Pyridoxine (mg/kg)	3.2	2.6	—	—
Riboflavin (mg/kg)	3–6	4.7	1	50
Thiamin (mg/kg)	0.2	1.2	0.4	0.2
Vitamin B_{12} (μg/kg)	55	48	—	540
Vitamin E (mg/kg)	1	1	—	—
Amino acids				
Arginine (%)	4	4	0.5	4
Cystine (%)	0.6	0.6	—	1
Histidine (%)	1–6	1	0.2	2
Isoleucine (%)	1–2	2	0.5	4
Leucine (%)	4–12	3	0.9	6
Lysine (%)	4–9	4	0.9	5
Methionine (%)	0.9–1.1	0.7	0.2	1
Phenylalanine (%)	2–6	1.9	0.6	3
Threonine (%)	2–4	1.9	0.6	3
Tryptophan (%)	0.3–1.1	0.2	—	1
Tyrosine (%)	1–2	0.8	0.7	2
Valine (%)	3–8	3	—	5

Continued next page

Table 10.7 — (*continued*)

Blood meal	Fish meal	Crab meal	Condensed fish solids	Dried fish solubles	Oyster shell flour	Hydrolyzed poultry feathers
91–93	93	93	51	92	100	94
84–90	71	33	62	68	1	85–93
0.18–2	17	2	13	8	—	2.6
1.1	1.1	12	2	1.1	—	0.6
0.3–0.5	0.5	16	1.2	—	38	0.2
9–11	96	35	95	—	—	—
0.3–0.4	0.07	0.5	0.06	—	0.3	—
0.04–0.2	—	1	0.04	—	0.3	—
6–7	9	144	23	—	133	—
0.2–0.4	1.3	2	1.4	—	0.07	0.75–0.9
0.4–1	—	0.5	3.4	—	0.1	—
0.4	—	0.9	6	—	0.2	—
—	—	—	75	—	—	—
—	—	—	0.4	—	—	—
306–832	—	2150	7900	5677	—	977
—	—	—	—	—	—	—
31–35	—	47	330	251	—	34
1–6	—	6	69	49	—	12
—	—	—	—	—	—	—
1–5	—	6	28	8	—	2.4
0.4	—	—	11	—	—	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
4	—	2	5	3	—	6
1	—	—	3	—	—	4
5	—	0.5	5	3	—	0.6
1	—	1.3	3	2	—	5.3
11–12	—	1.7	5	3	—	7.4
8–9	—	1.5	5	3	—	2
1	—	0.5	2	1	—	0.6
6	—	1.3	3	1	—	4.7
4	—	1.1	2	1	—	5.0
1	—	0.3	2	1	—	0.5
2	—	1.3	1	1	—	2.8
7–8	—	1.6	3	2	—	6.5

Source: National Academy of Sciences (1974), Spencer (1985).

Antioxidants such as butylated hydroxy anisole (BHA), butylated hydroxytoluene (BHT) or tocopherol may be added to fats to retard oxidation and rancidity. Propylene glycol, ($C_3H_8O_2$) sorbic acid ($C_6H_8O_2$) and potassium sorbate ($C_6H_7O_2$) and potassium sorbate ($C_6H_7KO_2$) may be used to prevent mold and bacterial growth.

By 1989 all pet food material in U.S. must meet nutritional adequacy (Anon.

1987). There are two procedures for establishing a nutritional claim and they are 'laboratory analysis' and 'animal feeding test'. For the laboratory test it is necessary to demonstrate required nutrients and apparent digestibility. The required nutrients include essential amino acids, dry matter digestibility and protein digestibility. A company must resubmit data every two years or whenever a product undergoes a significant change. The label must be complete nutritionally, including the test used to determine the category into which the product fits. The following information must be on the label:

(1) basis claim (e.g. complete and balanced),
(2) life-stage or cycle (e.g. all stages or adult cat maintenance),
(3) nutritional basis for claim (e.g. 'based on AAFCO — protocol feeding test' or 'based on NAS — NCR nutritional criteria').

ROUGH FISH FOR MINK FEED

Feeding mink with cleaned raw marine fish as the only source of protein results in hypochromia:iron-deficiency. Fish can be supplemented with an organic chelate containing ferric iron chelated with glutamic ($C_5H_9NO_4$) or ribonucleic acid (RNA) (Ender, 1975) to prevent iron deficiency. The enzyme thiaminase in fish flesh can also be a problem in feeding mink since this enzyme depletes the flesh of the vitamin thiamin.

Mink need a uniform-quality, stable, easily storable, non-thiaminase-active fish product. Therefore, there is a need for an inexpensive product to be made on-board ship or at dockside. A product fitting this description can be manufactured by grinding (0.635 cm ($\frac{1}{4}$ in) plate) the fish, extruding the ground fish in a thin layer (1.27 cm ($1\frac{1}{2}$ in)) into a steam-cooking chamber, quickly heating the product to 82°C (180°F) and holding at this temperature for 5–10 minutes (to destroy enzymes), grinding the cooked product, pressing the cooked ground fish for 5 minutes at 0.7–1.05 kg/cm^2 (10–15 psi) (reduces storage area by 50%), cooling the press cake for one hour and then freezing.

MINK FEED FROM POULTRY BY-PRODUCTS

Poultry head, fat and viscera, which include intestinal tract, lungs, spleen, windpipe, preen gland (uropygial gland, oil-producing gland located at the base of the tail feathers) and reproductive organs, can be used for feeding fur-bearing animals including mink. The product is generally prepared by washing, grinding and freezing the by-product and it is held frozen until just before feeding.

A typical mink ration may consist (Mountney, 1976) of:

25% high-quality protein — horse meat
cheese
rabbit
whale meat

20% poultry by-products
20% supplemented cereal
15% tripe
15% whole fish
5% liver

The composition of chicken by-products can be found in Tables 10.7 and 10.8.

DRY MINK FEED

Feeding fresh fish and fish or meat by-products to mink creates different problems depending on the raw material, such as seasonal availability of raw material, fur defects caused by fish such as coalfish, whiting, hake and turbot, the presence of thiaminase in fish, and the possibility of botulinum toxin. For these reasons, a heated dry feed is often desirable. The composition shown in Table 10.9 of dry mink feed (Gillies 1975) has proven successful. The product is then pelleted.

PORPOISE, DOLPHIN AND SEAL FOOD

Since porpoises, dolphins and seals consume primarily fresh fish, there is a need for a substitute feed for captive animals. A protein gel has been developed (Gillies, 1975) by comminuting whole fresh fish, dissolving the aqueous fraction and forming an emulsion of it with the oil fraction. The protein fraction is then coagulated to form a gel and pasteurized.

Other processes have incorporated 1–5% kelp (seaweed) with frozen ground fish, 1–1.7% NaCl, sodium tripolyphosphate ($Na_5P_3O_{10}$) and water. The ground and mixed product is passed through an orifice-type colloid mill to produce a gel and then pasteurized 82–88°C (180–190°F) with steam.

FISH-TANK FEEDING GEL

A gel to maintain food for fish in a palatable form for extended periods of time in a fish tank is needed.

The compositions (Gillies, 1975) of dry fish-food mixtures which have proven successful are given in Table 10.10. When ready to use 1 part of dry fish food is mixed with 3 to 5 parts of 49–100°C (120–212°F) water to form an agglomerate mass (firm gel) which is added to the fish tank.

POULTRY BY-PRODUCT USE

Poultry heads, feet and viscera (intestinal track, lungs, spleen, windpipe, preen gland and reproductive organs) make satisfactory pet food. Viscera is also used as a digest ingredient to make a dry palatability enhancer. It is first washed and ground, then often mixed with meal or pellets from plant sources; an increasing amount is

Table 10.8 — Composition of chicken by-products

Composition	Broilers whole raw	Cull hens, whole raw	Day-old chicks whole raw	Hatchery by-products		Eggs with shell raw	Feet raw	Gizzards raw	Heads raw feet,	Offal with feet, raw	Offal without raw
				Broiler type	Egg type						
Dry matter	24	58	24	35	29	34	47	25	33	31	27
Dry basis											
Protein (%)	77	28	57	22	32	37	53	80	58	42	44
Fat (%)	20	35	23	10	18	31	23	10	18	42	42
Fibre (%)	—	0.9	3.6	—	—	0	—	0	—	—	0.7
Calcium (%)	—	—	—	25	17	4.4	—	—	—	2.6	1
Phosphorus (%)	—	—	—	0.3	0.6	—	—	—	—	1.3	0.7

Source: National Academy of Sciences (1974), Vandepopuliere (1984).

Table 10.9 — Composition of a dry mink feed

Ingredient	Percentage by weight of dry mink feed
Comminuted fresh fish are heated to 60°C, oil removed by centrifugation and a spray-dried fish meal with 60% protein and 6% lysine is produced	47
Dry boiled potatoes or grain	18
Lard	9
Sugar	8
Molasses	5
Casein	4
Barley husk meal	4
Fish solubles	2
Dry yeast	2
Vitamin preparation	0.88
Combined iron preparation	0.12

Source: Gillies, 1975.

Table 10.10 — Composition of a dry fish food

Ingredient	Percentage in formula A	Percentage in formula B
Dried ground shrimp	84.2	—
Oyster, shrimp, clam, fish or crab meal	—	80–92
Kelgum (mixture of locust bean gum and fermented corn sugar)	0.5–5.0	0.5–5.9
Guar gum	0.5–5.0	0.5–5.0
Borax ($Na_2B_4O_7$)	1.2	1.5
Citric acid ($C_6H_8O_7$)	1.2	1.5
Methylparaben ($C_8H_8O_3$)	0.95	1.1
Sodium propionate ($C_3H_5NaO_2$)	1.9	2.3
Iron oxide (Fe_2O_3)	0.95	—
Dicalcium phosphate (or suitable desiccant)	0.95	1.0

Source: Gillies, 1975.

being canned. Due to the increasing consumer demand for prime poultry parts (legs, thighs and breasts) a large volume of poultry necks and backs are used as pet food ingredients.

FROZEN FISH USE

Cats, even though fond of fish, usually find thawed frozen fish an unacceptable commerical cat food item. It is believed that the enzymatic degeneration of the 5'-nucleotide content of fresh fish during freezing and thawing is responsible for the rejection of the thawed product by cats. A typical formulation (Gillies, 1975) in which a 5'-nucleotide is present as an additive, and therefore is acceptable to cats, is as given in Table 10.11. This product is mixed and cooked at 71–77°C (160–170°F) for 5–15 minutes, sealed in small cans (307×113 mm) and retorted at 121°C (250°F) for 50 minutes.

Table 10.11 — Composition of fish-based canned cat food

Item	Percentage
Thawed fish (ground 9.5 mm ($\frac{3}{8}$ in))	60
Beef (ground 9.5 mm ($\frac{3}{8}$ in))	10
Meat by-products (ground 9.5 mm ($\frac{3}{8}$ in))	15
Chicken	14
Vitamins and minerals	0.6
Disodium guanylate and/or guanylic acid ($C_{10}H_{14}N_5O_8P$)	0.01
Disodium inosinate and/or inosinic acid ($C_{10}H_{13}N_4O_8P$)	0.01

Source: Gillis, 1975.

CLAM WASTE

Portions (bellies, stomach, livers, other organs and small amounts of muscle) of sea clams (*Mactra solidissma*) are discarded during the shucking operation and this is referred to as clam waste. This fresh waste is washed to remove sand, shells and salt, sometimes ground, heated to 71°C (160°F) and are then combined with a thickener (1–10%) or binder (gums, seaweed extracts, agar, pectins or synthetic products such as methyl cellulose, sodium carboxymethyl cellulose, propylene glycol esters of alginic acid) and cooled to obtain the desired consistency for pet food. The product is placed in cans and vacuum sealed and then heat sterilized to produce a soft gel which may be spooned.

DRIED BLOOD IN PET FOOD

Dried blood, which has been coagulated with steam and dried when coarsely ground is called blood meal. If it has been finely ground it is called blood flour. This product is approximately 85% excellent quality protein. Blood meal is not particularly

palatable and is usually used at low levels and mixed with well-liked foods. In a gruel (thin water mixture) blood has a tendency to settle and some processors make a soluble blood flour, in which the fibrin has been removed, to alleviate this problem.

SUMMARY

Since pet food manufacturing is a fairly profitable endeavor, this industry has been very innovative in utilization of animal by-products. It has also built some very efficient, modern, technologically advanced plants. Because of this environment it has also been a leader in new techniques for processing food and it is anticipated that the pet food industry will continue its leadership in efficient animal by-product utilization.

REFERENCES

Alpo (1987) *Alpo Beef Chunks Dinner.* Label Allentown, Pennsylvanian, Alpo Petfoods.

Anon (1986) Renderer upgrades pet food with cold process. *National Provisioner.* June 7, p. 24–36.

Anon (1987) Industry responds to improve regulations of petfoods. *Petfood Industry.* Nov.–Dec. p. 10–12.

Balaz, A., Bone, D. P. and Shannon, E. L. (1976) US Patent 3 959 511, Washington, DC.

Bernotavicz, J. W. (1975) US Patent 3 922 353, Washington DC.

Bone, D. P. (1977) US Patent 4 039 689, Washington DC.

Bone, D. P. and Shannon, E. L. (1975) US Patent 3 883 672, Washington DC.

Bone, D. P. and Shannon, E. L. (1977a) US Patent 4 029 823, Washington DC.

Bone, D. P. and Shannon, E. L. (1977b) US Patent 4 006 266, Washington DC.

Brody, J. (1965) *Fishery by-products technology.* AVI, Westport, Connecticut.

Burkwall, Jr, M. P. (1976) US Patent, 3 974 296, Washington DC.

Burrows, I. E., Chaney, P. A. and Ariss, S. A. (1977) US Patent 4 041 181, Washington DC.

Cagle, J. D. (1975) US Patent 3 882 257, Washington DC.

Carnation (1987), *Friskies Buffet Mixed Grill For Cats.* Label. Carnation, Los Angeles.

Charter, W. M. (1973) US Patent 3 765 902, Washington DC.

Clausen, E. E. (1977) US Patent 4 039 692, Washington DC.

Carbin, J (1984) *Distillers Dried Grains with Solubles for Growing Puppies.* Distillers Feed Conference, Cincinnati.

Carbin, J. (undated) *Nutrient requirement and nutrient recommendations for dogs.* NRA General Publication No 409-E. National Renderers Association. Des Plaines, Illinois.

Ender, F. (1975) US Patent 3 911 117, Washington DC.

Gillies, M. T. (1975) *Fish and shellfish processing.* Noyes Data, Park Ridge, New Jersey.

Hildebolt, W. M. (1975) US Patent 3 916 029, Washington DC.

Horn, C. P. (1975) Personal communication. Star-Kist Foods, Long Beach, Calif.

Kern, J. P., Lemarechal, J. and Desforges, M. (1975) US Patent 3924011, Washington, DC.
King, D. P. (1974) US Patent 3857989, Washington DC.
Kotthoff, L. L. (1975) US Patent 3922355, Washington DC.
Lugay, J. C. and Beale, R. J. (1978) US Patent 4070490, Washington DC.
McCulloch, M. G. and Nelson, W. E. (1977) US Patent 4020187, Washington, DC.
Mann, I. (1962) *Processing and Utilization of Animal By-Products.* Food and Agric. Org. of UN. No. 75.
Miller, T. A. and Hansen, C. J. (1975) US Patent 3908025, Washington DC.
Mountney, G. J. (1976) *Poultry products technology.* AVI, Westport, Connecticut.
National Academy of Sciences, (1974) *Nutrient requirements of dogs.* National Academy of Sciences, Washington DC.
National Academy of Sciences, (1978) *Nutrient requirements of cats.* National Academy of Sciences, Washington DC.
OSU (1987). Analysis. Not published.
Palmer, H. C., Horrocks, D. and Buckley, K. (1975) US Patent 3873736 Washington DC.
Perry, T. W. (1984) *Animal life-cycle feeding and nutrition.* Academic Press, New York.
Pet Food Institute (1983) *SAMI Report.* Pet Food Institute, Washington DC.
Pet Food Institute (1987) *SAMI says . . . Petfood Industry.* Nov/Dec. p. 8.
Pet Food Labels (1987) *Survey of pet food labels in Columbus, Ohio.* Unpublished.
Ralston Purina (1981) *Nutrition and management of dogs and cats.* St. Loius.
Reardanz, E. H. and Boudreau, J. N. (1976) US Patent B-441,789, Washington DC.
Reesman, S. H. (1974) US Patent 3843815, Washington DC.
Riggs, N. S. and Sarno, F. S. (1975) US Patent 3897572, Washington DC.
Spencer, C. (1985) *The utilization of meat by-products in the pet food industry*, Special Report, Department of Animal Science, Ohio State University, Columbus.
Stocker, C. T., Schara, R. E., Marshall, W. E., Hayes, Jr, J. T. and Glicksman, M. (1976) US Patent 3965268, Washington DC.
Subcommittee on Cat Nutrition (1986) *Nutrient requirements of cats*, revised edition, Washington, DC, National Academy Press.
Subcommittee on Dog Nutrition (1985) *Nutrient requirements of dogs*, Washington DC, National Academy Press.
Vandepopuliere, J. M. (1984) *Animals as converters of by-products from animal preocessing.* Proceedings of an International Symposium, Wageningen, Netherlands.

11

Sea food by-products

INTRODUCTION

Sea food products are obtained from a wide variety of species of animals, and of those animals only a portion is usually separated from the carcass and used as food. The remainder is a by-product, often high in protein, that can usually be processed into useful products. When harvesting fish and crustaceans, there are many species that are not used as human food that are also caught. These 'trash fish' can consequently be processed into useful by-products. Two major references in this area are Tressler and Lemon (1951) and Windsor and Barlow (1981) and these should be consulted for additional details on sea food by-products. Examples of the more important by-products obtained from sea foods are discussed in this chapter.

SURIMI

Fish are headed, gutted and cleaned (sometimes the backbone is removed) in water and then the flesh is separated with a belt-drum-type separator (3–4 mm (0.12–0.37 in) perforations). Surimi is the mechanically deboned fish flesh that is repeatedly washed in 5–10°C (41–50°F) water until all the water-soluble proteins are removed and to which a cryoprotectant is added. A good review of surimi technology may be found in Lee (1984). The volume of water used is 5–20 times that of the fish. This washing removes not only water soluble proteins but also other undesirable substances and enzymes and this results in a concentration of the actomyosin. The last wash can contain 0.01%–0.3% sodium chloride (NaCl). The product is de-watered with a screw press and strained to remove black skin, bones and scales. A silent cutter or ribbon blender is used to mix the cryoprotectants, which normally consist of 4% sugar ($C_{12}H_{22}O_{11}$, up to 8% can be used, but this usually makes the product too sweet), 4% sorbitol ($C_6H_{14}O_6$, not so sweet) and 0.2% polyphosphates (triphosphate ($Na_5O_{10}P_3$) and pyrophosphate ($H_4O_7P_2$) have equal cryoprotective effect). The cryoprotectants' role is to prevent actomyosin from denaturing during frozen storage. Table 11.1 indicates terminology that is used in the processing area and Fig. 11.1 gives a flow chart of surimi manufacturing.

Surimi is graded using many factors depending upon its ultimate use. Some of the currently used and proposed standards may be found in Table 11.2.

Table 11.1 — Terminology in surimi production

Surimi	Mechanically deboned fish flesh that has been washed with water and mixed with cryoprotectants.
Minced fish	Mechanically separated fish flesh that has not been washed.
Kamaboko	Products made from surimi that are mounted on a wooden plate and steamed or broiled.
Chikuwa	Products made from surimi that are broiled.
Tempura	Products made from surimi that are fried.
Kaen-surimi	Surimi containing salt.
Muen-surimi	Surimi without salt.

Source: Lee (1984); Connell and Hardy (1982).

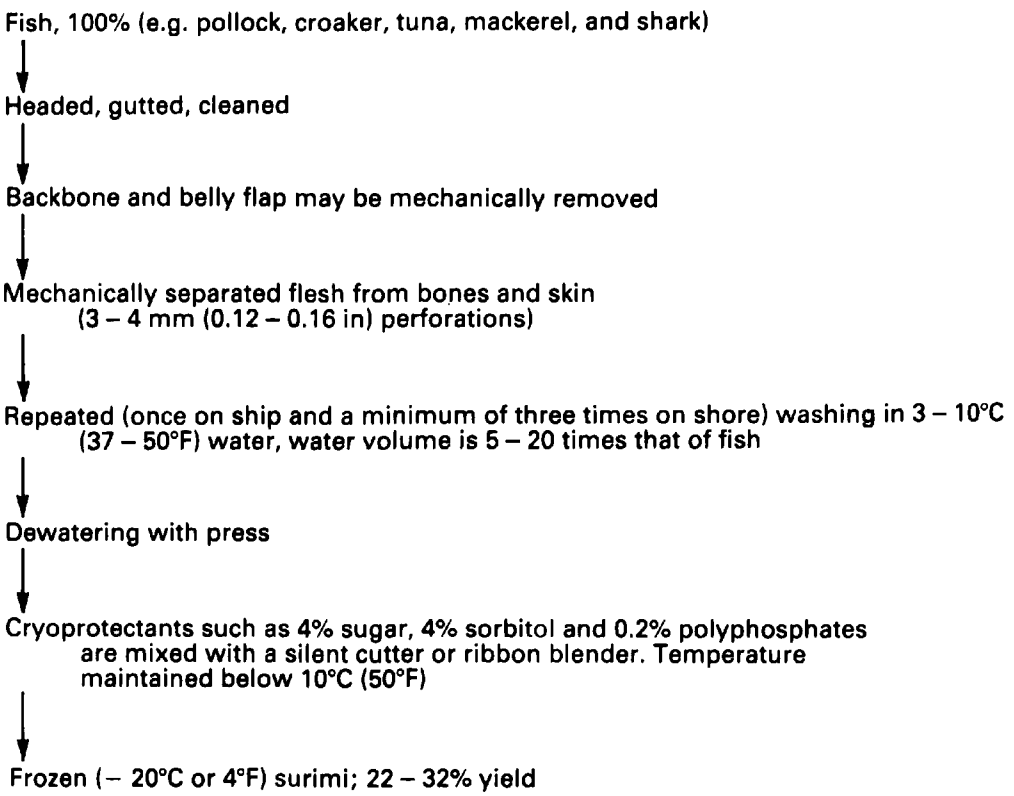


Fig. 11.1 — Surimi manufacturing.

Surimi may be utilized in manufacturing many reformed meat-like and seafood items. For example, surimi may be used as raw material for artificial crab-leg manufacture, fish sausage-like items, fish wiener-like items, moulded fish-like

products and fibrous fish-like products. The various processing possibilities are outlined in Fig. 11.2.

Table 11.2 — Properties used or proposed for grading surimi

Chemical and visual
Moisture level
pH
Whiteness–Hunter colour meter
Impurities–black skin and bones
Physical properties
Expressible drip — pressed
Viscosity — in 3.5% NaCl solution
Gel-forming ability (constant moisture)
Gel strength — plunger
Folding test — crack when folded
Firmness — sensory
Chewiness — Energy used with repeated compressions
Elasticity — tensible force to break sheet
Water binding — slope of gel strength versus moisture
Frozen storage
Freeze–thaw cycles — pressed fluid

FISH PROTEIN CONCENTRATE (FPC)

In 1962, the U.S. Bureau of Commercial Fisheries (BCF) mounted efforts to produce a fish protein concentrate suitable for human consumption (Ockerman and Stombaugh, 1987). The resulting FPC A was a tasteless, odourless, colourless powder with a minimum of 67.5% crude protein (percentage of nitrogen×6.25) and a maximum of 0.75% fat. FPC A was designed for use as a 5–10% component of most familiar foods without compromising their acceptability. Arriving at this extreme state of blandness required a solvent-extraction technique that made the product expensive.

In addition, FPC A ran afoul of regulatory provisions. Becuase FPC A was prepared from whole fish, including viscera, bones, scales, etc., it contained substances classified as adulterants as defined in Section 402 of the U.S. Food, Drug and Cosmetic Act (FDA). The U.S. National Academy of Sciences reviewed the safety of FPC and concluded that the product was highly nutritious, stable, safe and capable of being economically produced and marketed. However, due to regulations and other restraints, FPC has not been utilized to any major extent in the U.S. It was used in other countries until 1978.

The second (FPC B) and current product has a 10% fat content, as well as a

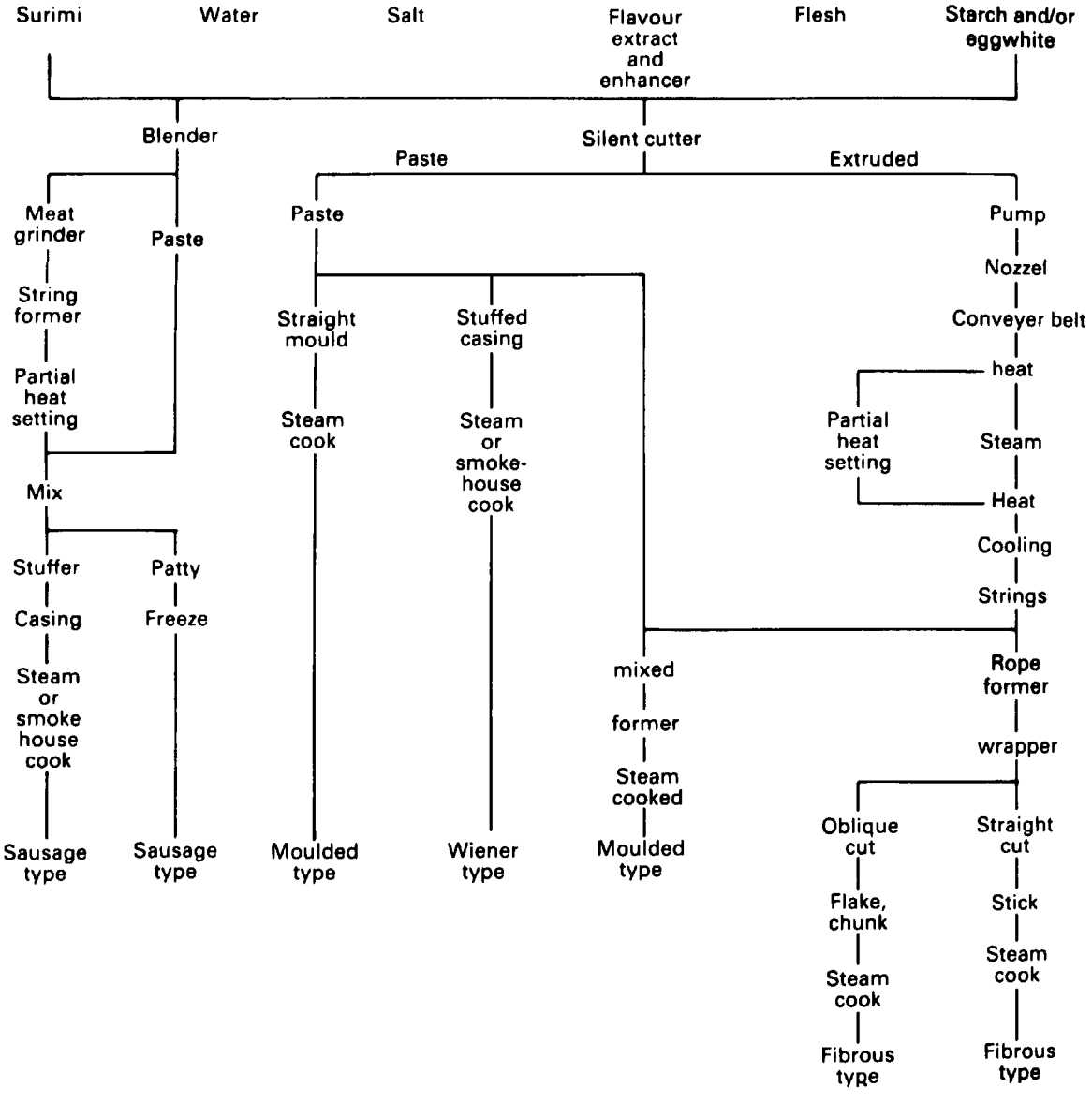


Fig. 11.2 — Processing procedure using surimi.

distinct fishy smell and taste, which means that its presence in a common food is not easily concealed. FPC B can be produced from almost any kind of fish, is easy to transport and distribute, and stores well (up to 2–3 years in Indian and African tests). It is recommended to be used at the level of 35 g/person/day (1.25 oz/person/day). Because it is purposely less bland than FPC A, its processing technology is comparatively simple and much less costly. Extensive taste tests showed that FPC B is well accepted by people accustomed to a diet containing fish, notably those in Africa and Asia.

A fish protein concentrate that is bland in flavour and also has good functional properties has been produced by enzymically (using e.g. papain, pancreatin, bromelin, ficin, or Rhozyme P-11) modifying whole fish protein and removing the modified proteins as protein–phosphate complexes using a linear condensed phosphate such

as sodium hexametaphosphate ($(NaPO_3)_4$). The protein–phosphate complexes are precipitated by lowering the pH to 2.5–3.5 with an acid, and the precipitated complex is centrifuged, washed and extracted with a polar solvent to remove lipids. It is then neutralized with a base, and 10–20% carbohydrates are added. The mixture is then drum-, spray- or freeze-dried.

FISH MEAL AND OIL PRODUCTION

Fish meal is a popular animal feed because of its high nutritional value. When correctly processed it has a high level of essential amino acids (especially lysine ($C_6H_{14}N_2O_2$)), B-complex vitamins (B_{12} ($C_{63}H_{88}CoN_{14}O_{14}P$), choline ($C_5H_{14}NO$), niacin ($C_6H_5NO_2$), pantothenic acid ($C_9H_{17}NO_5$) and riboflavin ($C_{17}H_{20}N_4O_6$)) and minerals including calcium, copper, iron, phosphorus, and other trace minerals. It is also popular because it is low in fibre and is easy to produce. For swine, cattle, and poultry, it is often added at approximately a 3% rate to their cereal diets. Of course, care must be taken to prevent 'fishy' odours and flavours being imparted to animal tissue or animal products such as egg or milk, so the following levels are often used (Anon, 1945):

cattle	907 g/day/454 kg (2 lb/day/1000 lb)
pigs	113–227 g/day ($\frac{1}{4}$–$\frac{1}{2}$ lb/day) according to weight
poultry	
chicks	not more than 5% of ration
hens	not more than 10% of ration
sheep	45–91 g/day ($\frac{1}{10}$ to $\frac{1}{5}$ lb/day) according to weight

Fish meal, fish solubles and fish oils are obtained by cooking and pressing whole fish, such as herring, menhaden, pilchards, sharks, and grayfish, or trash fish and/or fish scraps or cannery wastes, which are often called 'gurry' from filleting and canning operations. Fish scraps normally consist of the head, skeleton and adhering proteinaceous tissue. Fish meals are usually produced in a ratio of 3 : 1 when compared with fish oil. Yield of both is approximately one-sixth to one-eighth the weight of the original fish or fish scraps.

The chemical composition of fish meal will vary with the raw material used — the species of fish and whether whole or parts of fish are used — and the processing procedure. Some ranges of composition can be found in Table 11.3.

Fish meal meanufacturing follows two basic techniques called wet reduction and dry rendering. For more information on rendering see Chapter 3. Also, solvent extraction methods using acids, bases, hydrogen peroxide (H_2O_2) or sulphur dioxide (SO_2) are sometimes used and these solvents are later removed. The addition of antioxidants is sometimes necessary, particularly for highly oil-containing fish. The advantages and disadvantages of wet or dry rendering may be found in Table 11.4.

The wet reduction method (see Fig. 11.3) is normally a continuous process adaptable to handling large quantities of fish. If the supply of fish is greater than the processing facilities, it is possible to preserve the fish in 15–25% (based on remaining water in the fish) solvent (e.g. ethanol (C_2H_6O), isopropanol (C_3H_8O), *n*-butanol ($C_4H_{10}O$), *sec*-butanol ($C_4H_{10}O$) and isobutanol ($C_4H_{10}O$)) which normally would

Table 11.3 — Chemical composition of fish meal

Component	Percentage range	Comment
Protein, fish flesh	15–18	
Amino acids, fish flesh		15–18% protein
Arginine	0.84–1.03	in fish flesh
Histidine	—	in fish flesh
Isoleucine	0.76–0.93	in fish flesh
Leucine	1.12–1.38	in fish flesh
Lysine	1.31–1.60	in fish flesh
Methionine	0.43–0.53	in fish flesh
Phenylalanine	0.55–0.68	in fish flesh
Threonine	0.65–0.79	in fish flesh
Tryptophan	0.15–0.18	in fish flesh
Valine	0.79–0.97	in fish flesh
Protein, fish meal	50–77	Most meals 60–65
Fat	5–15	Desired maximum 8% Low fat is dusty
Ash	8–33	18% satisfactory 12% in high-protein meal 33% in low-protein meal
Moisture	6–12	8% is satisfactory 12% subject to mould growth Less than 6% heating will occur
Crude fibre	Less than 1%	low-fibre feed
Vitamins		
B_{12}	0.1–0.33 mg/lb	
Choline	1500 mg/lb	
Niacin	30 mg/lb	
Pantothenic acid mg/lb		
Riboflavin	3 mg/lb	

Source: Brody (1965), Nielson (1950), U.S. Fish and Wildlife Service, (1962), Orr and Watt (1957).

be used in the subsequent extraction process. This solvent is added after disintegration, boiling, deboning, separation, pressing and partial dewatering (12–20% moisture). Wet reduction is useful with fatty fish such as menhaden, redfish, seaherring, pilchard (California sardine) and salmon cannery waste. It produces not only fish meal, but also fish scrap, fish solubles and fish oil.

The wet reduction method uses a continuous cooker with the product moved through the cooker by a screw conveyor. Later, steam is injected into the cooker and proper cooking coagulates the protein and releases the oil. Cooking rate can be varied by changing the steam pressure (usually 0.35 to 0.70 kg/cm^2 (5–10 psi)), and therefore by changing temperature, and by varying the conveyor speed. The cooking rate needs to be altered according to the raw material used.

Table 11.4 — Comparisons of dry and wet reduction methods of producing fish meal

	Dry method	Wet method
Type of operation	Small, batch, slower	Large, continuous, faster
Installation and cost of operation/capacity	More expensive	Less expensive
Ease of operation	Easier	More complex
Flexibility of operation	More	Less
Production capacity	Less	Greater
Yield of oil from low oil fish	Larger	Smaller
Yield fish solubles	No	Yes
Oil quality	Darker and inferior	Light and superior
Meal contains water soluble material	Yes	Usually does not

Source: Brody (1965).

After moist cooking, the cooked fish are fed into a continuous screw press encased in a cylindrical screen (perforations of approximately 1.2 mm ($\frac{3}{64}$ in) in diameter at the inlet end and approximately 0.8 mm ($\frac{1}{32}$ in) in diameter at the discharge end). The pitch of the screw flights progressively decreases and consequently increases the pressure on the cooked product. In some systems, pressure is applied and abruptly released to cause cellular rupture. The meal is dried in a direct flame, in a steam-jacketed dryer or in a steam-tube dryer. Since drying is often the most time-consuming process, the wet press cake can be temporarily preserved by mixing and storing it in alcohol (C_2H_6O) which may be subsequently removed by azeotropic distillation.

The press liquor is placed on a vibrating fine screen and the small particles captured are recombined with the press cake. The liquid is then heated to 90°C (195°F) and centrifuged or, for less desirable oil, allowed to rise (the water fraction settles) to obtain the oil. If settling is used, the oil is often washed in this process. After this separation, the oil is again polished using a centrifugal technique. Unfortunately, the vitamin content of fish body oil is not as high as the vitamin content of fish liver oil. After oil removal, the water portion (stickwater) is discarded or concentrated under vacuum to make fish solubles.

The press cake is fluffed and dried to approximately 8% moisture.

The dry rendering batch method (see Fig. 11.4) of fish meal production is primarily used on non-oily fish or non-oily fish offal such as cod and haddock canning waste or carcasses of grayfish or shark. Since this is a batch process, it is much easier to manipulate than the continuous wet reduction method.

The first step in dry rendering is the grinding of the large pieces and then placing them in a steam-jacketed cooker–dryer equipped with a power-stirring device 0.70–5.6 kg/cm^2 (10–80 psi) in the jacket). The cooker–dryer may be operated under

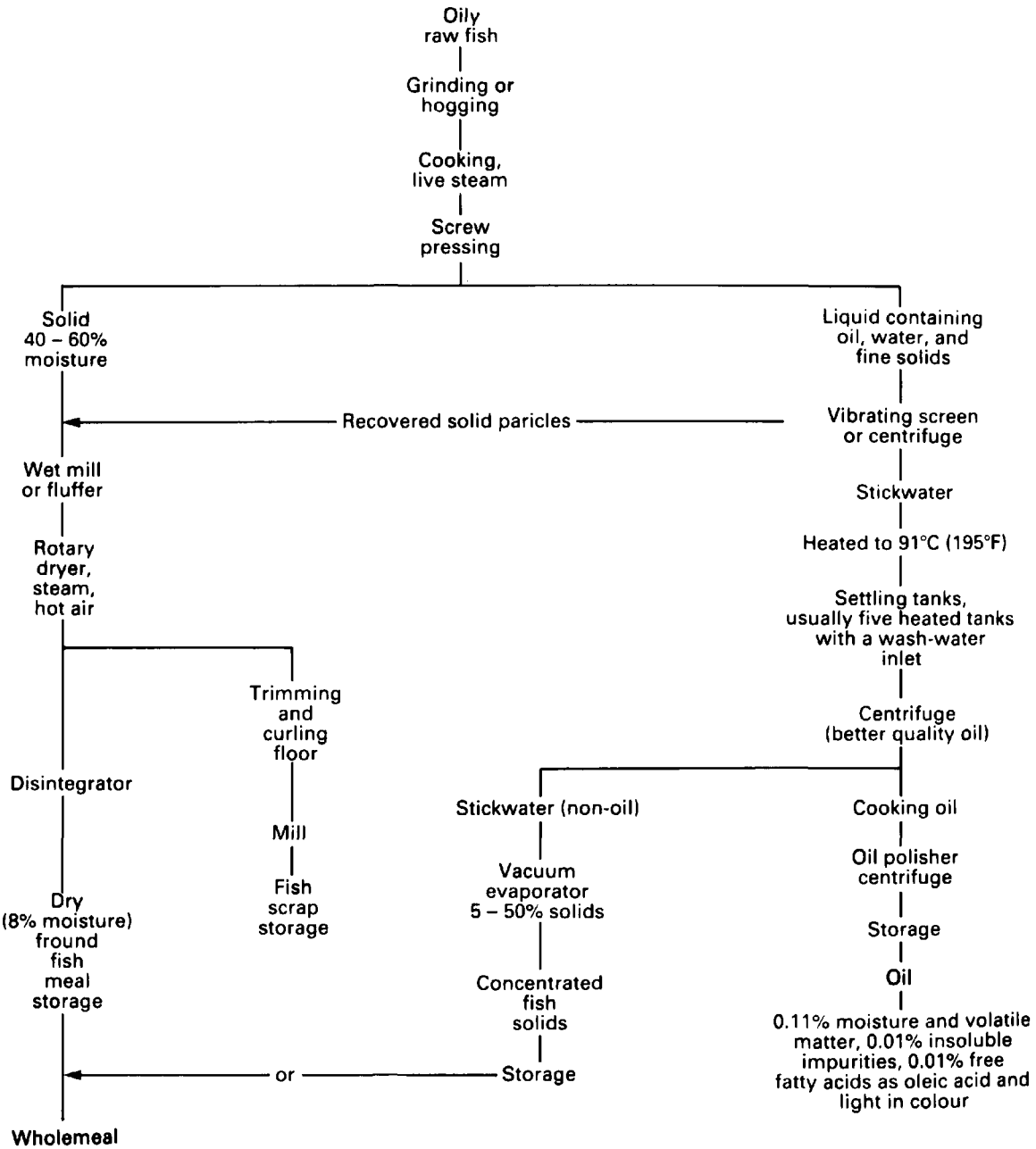


Fig. 11.3 — Continuous fish wet-reduction plant. From Brody (1965).

atmospheric pressure or under a vacuum. The meal is pressed hydraulically to remove the liquid. Due to the high temperature and long time necessary (6–7 hours for vacuum cooking) for cooking, the oil obtained is usually comparatively dark and is of inferior quality. In dry rendering, the water-soluble materials are retained in the meal.

HYDROLYSIS OF FISH PROTEIN

The protein portion of fish can be progressively hydrolysed into peptones, albumin or amino acids. Of the protein fraction, approximately 16%–22% is albumin, which has chemical properties similar to egg white.

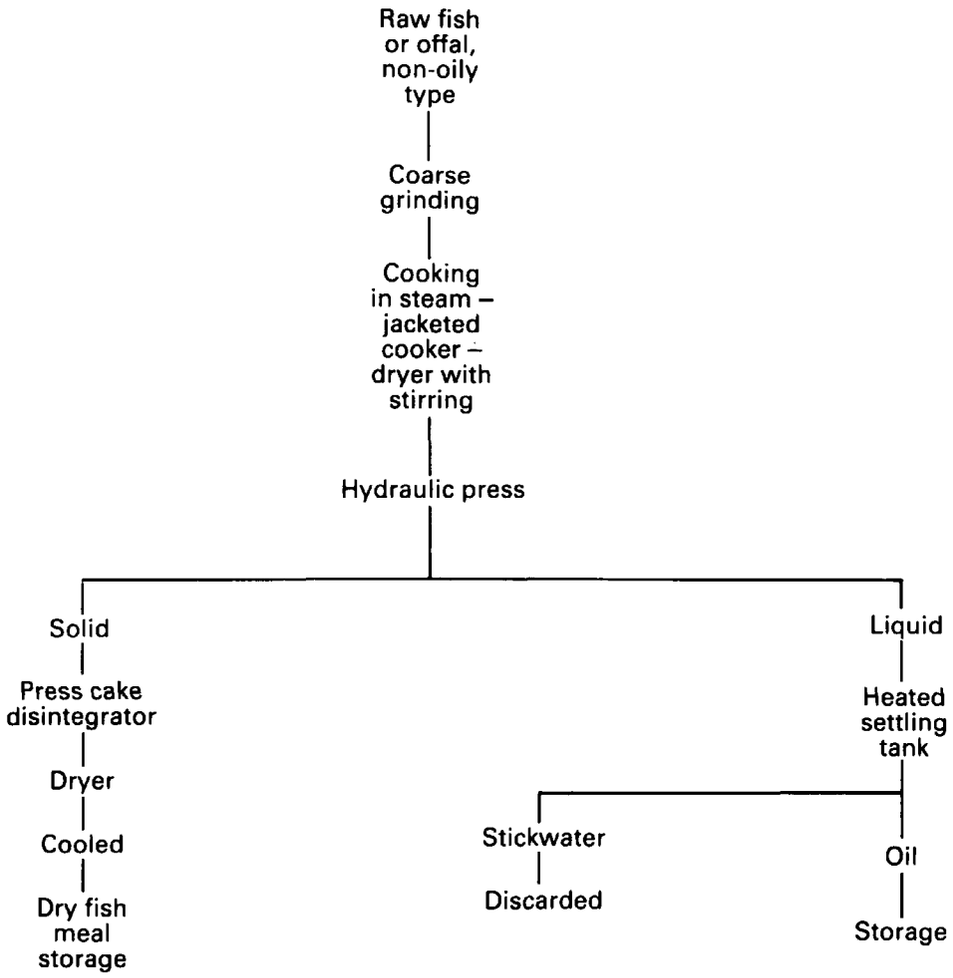


Fig. 11.4 — Batch fish dry reduction. From Brody (1965).

Peptones are partially hydrolysed proteins which are soluble in water and not heat coagulable. They are prepared by grinding the fish flesh with water and hydrolysing it with peptic or tryptic enzymes, or with acid or alkali at elevated temperature and pressure. The next step is the separating of the resulting layers and subsequent concentration, often including a step to remove salt or acid. To recover the product in solid form, spray drying is often used. Some of these products may have as much as 5–10% oil based on dry weight. For peptic hydrolysis, the flesh is heated to 100°C (212°F) for 5–10 minutes, cooled to 35°C (98°F), acidified to pH 2 with hydrochloric acid (HCl), treated with fish intestinal mucosa, which contains peptic enzymes, or commercial pepsin and incubated for 12 hours to 2 weeks at 35°C (98°F). After digestion, the mixture is centrifuged, the protein hydrolysate is heated to 80°C (144°F) to inhibit the enzyme, cooled, neutralized with sodium hydroxide (NaOH), filtered, concentrated to 30% solids and spray dried. For tryptic hydrolysis, the intestinal mucosa is replaced with pyloric caeca, which contains tryptic enzymes. Acid hydrolysis is accomplished with hydrochloric acid (HCl) or sulphuric acid (H_2SO_4) at a pH of 0.5–1.5 under pressure of 1.1 kg/cm^2 (15 psi) at 121°C for (250°F) for 15 minutes to 5 hours. The acidity of the liquid phase may be neutralized by adding a base or by passing it through a suitable ion-exchange medium. In alkali

hydrolysis, lye (NaOH) is substituted for the acid. The product is filtered and the acid or lye is removed by ion-exchange, then the product is concentrated and vacuum dried.

The peptones produced may be used for bacteriological culture media and are very helpful in cultivating pathogenic bacteria.

To extract albumin, low-fat fish, molluscs, and crustaceans are usually used. The flesh or scraps are minced in a 0.5% acetic acid ($C_2H_4O_2$) solution and cooked for 1 hour at 80–90°C (160–176°F) which partially hydrolyses and extracts most of the connective tissue. The unextracted material is washed to remove acid and digested proteins, pressed, ground, and extracted for 6–8 hours with ether ($C_4H_{10}O$), alcohol (C_2H_5O) or trichloroethylene (C_2HCl_3) to remove the fat. It is then vacuum dried for 2–3 hours at 50°C (122°F) to yield the insoluble technical grade albumin. To produce the food or pharmaceutical grade, it is further digested with caustic soda 6–8 g (0.2–0.3 oz) of NaOH in 500 l (132 gallons) water/100 g (3.5 oz) protein) for one hour at 25°C (86°F) and another hour at 80–90°C (176–194°F). The product is then neutralized with lactic acid ($C_3H_6O_3$) and spray-dried at 125–150°C (257–302°F). The finished product contains primarily polypeptides and very few amino acids. It can be used in place of egg albumin as a whipping, suspending or stabilizing agent. It is used in confectionery products, bakery products, ice cream, soap, puddings, custard, and mayonnaise. Industrially, it is used in paints, varnishes, lacquers, foam extinguishers, textiles, paper, resin replacements, leather, soaps, and cosmetics.

Amino acids can be prepared from fish protein by hydrolysis with enzymes, acids, or alkalis. The amino acids have been studied for use in the medical area and they may be used to supplement animal feeds.

Fish protein can also be hydrolysed by yeast, enzymes produced by moulds or bacteria. In these processes whole fish, molluscs, crustaceans or sea food remains are mixed with 7–10% molasses and the mixture fermented. The end product can be used for human food, animal feed or fertilizer. Fermentation is usually conducted at 28–35°C (82–95°F) for 18–24 hours. The product is then filtered, degreased by mechanical means, the solids concentrated to 50%, and the product then dried.

Plant enzymes (e.g. bromelain) have also been used to digest fish or fish mixed with fat. A pre-treatment with plant enzymes will also reduce the digestion time required when isolated proteolytic enzymes are used for hydrolysis.

CANNERY WASTE

In the salmon-canning industry, approximately one-third of the fish are classified as cannery waste. This waste, on average, is composed of 56% head and collar, 13% tail and fins, 4% liver, 11% roe, 5% milt, 10% digestive tract, and 0.7% heart. These percentages change with the season due to an increase in the amount of milt (male) and roe (female) during the spawning season.

Cannery waste can be fed directly to mink or processed into pet food, and the heads can be used as halibut bait. Fish offal has been fed in the initial growth phase to pigs, but it must be removed from the diet 6–8 weeks prior to slaughter to avoid a fish flavour in the tissue.

Salmon head oil can be added to canned salmon. Salmon oil is primarily produced from salmon offal.

Salmon eggs can be processed into caviar (smaller eggs), used as fish bait or as a raw material for the production of cholesterol ($C_{27}H_{46}O$), lipids and proteins. The salmon eggs are collected from the body cavity with the viscera and removed from it by hand. The eggs may then be frozen, salted or chemically preserved. For salting they are washed in salt water and then placed in a saturated brine solution containing colour additives for 20 minutes. They are then packed in boxes with salt sprinkled between the layers and allowed to cure at room temperature for one week. After curing, they are stored at 5°C (40°F).

Milt is also separated from the viscera. Each gallon of milt is treated with 0.13 gallons of caustic soda (NaOH) solution (600 g/l (5 lb/gallon)), which acts as a preservative and is the first step in processing.

Salmon eggs contain an average of 13% fat, 6.2% phospholipids (probably lecithin) and 0.4% cholesterol. The fat contains 3% cholesterol, has an iodine number of 200 and contains 6% unsaponifiables (53% of the unsaponifiables are cholesterol). The protein in salmon eggs is of high quality because of its relatively high level of lysine ($C_6H_{14}N_2O_2$), methionine ($C_5H_{11}NO_2S$) and isoleucine ($C_6H_{13}NO_2$).

Insulin (see Chapter 7) can also be obtained from fish. Cod, halibut, and pollak are the most frequently used species and the large islets or 'caps' which are located by the gall-bladder are collected. The caps contain a high concentration of insulin and are clipped off with scissors. The excised tissue is frozen with solid carbon dioxide (CO_2) or placed in 95% alcohol (C_2H_6O), acidified with 0.3% hydrochloric acid (HCl), and protected from sunlight. The alcoholic solution of tissue is then chilled and shipped for no more than 24 hours. Insulin is extracted from the tissue by filtering the alcohol solution, grinding the tissue and re-extracting with a 75% alcohol solution for 1.5 hours, filtering the alcohol and re-extracting as many as three times. The alcohol is then removed by vacuum distillation. The aqueous insulin solution is washed with ether and the alcoholic extract is converted to insulin hydrochloride.

In Japan, insulin is also obtained from bonito, albacore and yellow-fin tuna. In some procedures the whale pancreas is also used as a source of insulin.

Other biochemical products that could be obtained from fish include nucleosides and nucleic acids from testes; protamines (combined with 5-iododeoxyuridine ($C_9H_{11}IN_2O_5$, used in terminal cancer patients) from salmon milt; strepogenin or the 'protein utilization factor' (stimulates growth of certain microorganisms) from fish flesh; glutathione ($C_{10}H_{17}N_3O_6S$, coenzyme for carbohydrate metabolism) from the fish heart, liver, kidney or spleen; cortisone ($C_{21}H_{28}O_5$, anti-inflammatory action) from fish plasma; bile salts such as cholic acid ($C_{24}H_{40}O_5$) and deoxycholic acid ($C_{24}H_{40}O_4$) from gall bladder; ointment for skin from unsaturated fish oil fatty acids; cholesterol depressants from fish oil, fatty acids or esters; and proteolytic enzymes (used in leather bating and to produce protein hydrolysates and peptones) from pyloric caeca (blind tube-like sacs attached to the stomach near the pyloric end) of fish.

The pyloric caeca are extracted several times with a mixture of 90% acetone (C_3H_6O) and 10% ether ($C_4H_{10}O$) to obtain the active enzyme. The solid is dried under vacuum and ground to a 20 mesh size. The yellow powder is approximately 30% water soluble. The enzyme has a maximum activity between pH 8.0 and 8.7 and a maximum temperature between 40 and 50°C (105 and 122°F).

PROCESSING OF FISH STICKWATER

Fish stickwater is a by-product of fish canning. Fish heads, tails, viscera and whole fish are steam cooked (0.35 kg/cm^2 (5 psi)) for 7–15 minutes and pressed by a continuous screw press. The press cake contains approximately 50% moisture and after drying is called fish meal. The filtrate (5–10% solids) is known as press water. This press water is heated to 88°C (190°F) and centrifuged to remove the oil. The water portion then contains 1% oil, 0.75–1.25% insoluble proteins and 3–5% soluble proteins, and is now called fish stickwater. The pH of this is lowered to 4–5, the product heated to 82°C (180°F) until it is evaporated to a 50% solid content, which is called concentrated fish solubles.

ANIMAL FEEDS

Fish offal (heads, spines and similar bones, ventricular portions, skin and sometimes the intestines) may be mixed with straw, potato mash or other carbohydrates. It may also be mixed with mill by-products, such as bread, chaff and residual flour, and fermented at slightly elevated temperatures to produce a useful animal feed (Gillies, 1975; see also Chapter 10). Problems with this procedure are that large volumes of liquid must be handled and that feeds with pronounced tastes and odours are produced and these odours can be transferred to the tissue of meat animals. These processes also cause the generation of toxic carbohydrate–protein complexes, which are not desirable in animal feeds.

Suggested procedures for reducing these problems involve producing a fish broth from fish waste or by-products, de-oiling and concentrating (40% moisture) this broth, mixing with a carbohydrate, and then fermenting (with e.g. diplococci) at 16–25°C (61–77°F) to produce a pleasant-flavoured animal feed.

Fish solubles can also be fermented to produce a palatable animal feed. 'Cooker water' containing oil and protein is separated from the cooked meat in a cannery plant and combined with 'press water' obtained from pressing the head and other waste material prior to making fish meal. This combination is known as 'stickwater' (average 5% solids). This stickwater is next vacuum evaporated to 50% solids, known as fish solubles. The fish solubles can be combined with molasses to make a palatable cattle feed. However, the stickwater can also be combined with molasses, the pH adjusted to 4.8, brewer's yeast added, and the mixture fermented. From the fermented product a distillate is removed. The slop is concentrated (50–60% solids), then the distilled spirits are recombined with the concentrate and additional molasses are added. This produces a nutritionally balanced, palatable livestock feed.

Fish solubles cannot be commercially dried and stored in excess of 50% solids due to their high degree of hygroscopicity. However, a dry non-hygroscopic product can be made by mixing condensed fish solubles with relatively low concentrations (10–20%) of exfoliated vermiculite. This type of product has been used in 'starter rations' for swine and poultry.

'Trash fish' (caught at a ratio of 6 pounds of trash fish to 1 pound of shrimp) can also be converted into animal feed. The fish are separated from the shrimp, ground and placed in a heated or sometimes a cooled liquid tank aboard ship. Also added to the tank are preservatives, water, enzymes and a chelating agent. When the ship

reaches port, the tank's contents are pumped to a land-based tank and heated to 70–80°C (158–176°F) for 30–60 minutes to inactivate the enzymes. The bones and scales settle to the bottom of the tank while the oil rises to the top. This procedure, after centrifuging, drying or evaporation, produces bone and scale meal (28% protein, 8% moisture, 55% ash and 5% oil), fish meal (61% protein, 8% moisture, 12% ash and 5% oil), fish solubles (42–50% solids, 32% proteins) and fish oil.

Pelleting of fish scrap or meal is often desirable because it reduces the volume, prevents rapid oxidation and charring and reduces the dustiness of the product.

Crustacean (e.g. shrimp, prawn, crawfish, crab) meals are utilized for aquaculture diets, not only for their nutritional value, but also as a supply of the carotenoid pigment astaxanthin ($C_{40}H_{52}O_4$). When this pigment is consumed by trout and coho salmon, it provides enhancement of integument and flesh colouration. A soybean oil extraction process has been developed to recover astaxanthin pigment from peeling waste.

FISH SILAGE

Fish silage, as well as silage from the entrails from warm-blooded animals, has been produced on a limited scale for a number of years and Raa and Gildberg (1982) present a recent review of the state of this art.

There are two principal methods of production and they include the 'acid-preserved silage' (inorganic and/or organic acids are added to lower the pH and the silage becomes liquid due to nauturally occurring enzymes) and 'fermented silage' (a fermentable sugar is added to the fish and either naturally occurring lactic acid bacteria or a starter culture is used to generate lactic acid and lower the pH). The fermentation technique has currently not been used commercially.

The fish silage produced may be used as a protein supplement to animal feed and may be fed as a liquid or mixed with carbohydrates. If the fish had a high oil content, this oil needs to be removed (if oil is greater than 2% net weight) before feeding since high fish-oil levels will impart a 'fishy taint' to the animal products and rancid oil lowers the nutritional value of the feed.

The natural alternative to fish silage is fish meal, and the advantages of silage in contrast to meal include (Raa and Gildberg, 1982):

(1) Fish silage does not putrefy even when stored at high temperature and there are less pollution problems encountered in its production.
(2) Fish silage is almost sterile and *Salmonella* is destroyed.
(3) The scale of fish silage production can be varied without affecting the economy of production.
(4) Energy requirements of production are very low compared to fish meal.
(5) Fish silage mixed with carbohydrates can be sun-dried without fly infestation.

The disadvantages of fish silage compared to fish meal include:

(1) Fish silage is more bulky and expensive to transport.
(2) There are some nutritional disadvantages to fish silage, particularly if fed at high levels.

Production of fish silage

The production of silage by the inorganic acid (e.g. sulphuric (H_2SO_4), hydrochloric (HCl) or phosphoric (H_3PO_4) acids) techniques requires lowering the pH to below 2 for preservation. This can be accomplished by adding 9 l (2.4 gallons) of a 14 N inorganic acid (e.g. 6.3 kg (13.9 lb) or 3.4 l (0.9 gallons) of concentrated sulphuric acid) for boney fish and 4 l (1.1 gallon) of a 14 N inorganic acid (e.g. 2.8 kg (6.2 lb) or 1.5 l (0.4 gallons) of concentrated sulphuric acid) for oily fish (with low ash and protein content) per 100 kg (220 lb) of fish. This acid level requires neutralization prior to feeding and the addition of 1–5 kg (2.2–11 lb) chalk (calcium carbonate, $CaCO_3$) per 100 kg (220 lb) of silage is often used. This produces a high salt level in the silage, which is undesirable from a nutritional standpoint.

Organic acids (e.g. 3% of formic (CH_2O_2), propionic ($C_3H_6O_2$) acids) are more effective than inorganic acids. The organic acids do not have to be neutralized before feeding, but the organic acids are more expensive. In order to reduce the price of production, a mixture of organic and inorganic acids are often used to make this silage.

Nutrition of fish silage

Amino acids are fairly stable in fish silage. The thiaminase enzyme system will often degradate vitamin B_1, causing a thiamin deficiency. This loss of thiamin can be avoided by heating the silage to boiling, thus destroying the enzyme system. Oxidation of lipids has been reported to be responsible for the sometimes poor nutritional value reported for fish silage. It is not currently known if all pathogens are destroyed by silage production; therefore, heating seems advisable and this also improves the nutritional value.

The nutritional value of fish silage has been reported as a good source of protein, but other reports indicate that it is inferior to fish meal. Many of these reported differences are probably due to silage quality and level of incorporation into the animals' feed. Certainly high salt levels will reduce feed intake and growth. To reduce carcass off flavours, a fish lipid level of less than 1% (below 0.6% in the last few days before slaughter) of the dry weight is often recommended. A level of 5–10% of the dry weight of the diet is used for pigs. Fish silage has been used satisfactorily at the 30% of total protein level for chickens and at the 12–23% level for broilers. The 30% level resulted in a 2.7% oil content which resulted in carcass taint but the eggs were of normal, good quality. Other feeding trials resulted in lower nutritional values when fish silage was used for poultry feed, depending on the level of inclusion. The net protein utilization has been reported as ranging from 52% to slightly above 70% for fish silage.

The nutritional value of fermented fish silage has been reported as good, and biological value similar to skimmed milk powder or fish meal has been obtained. In most reports, the feeding value of fermented silage is superior to inorganic-acid-produced silage.

FISH OILS

Fish species can be divided into two categories (see Table 11.5) based on the structure of their skeleton. This division also separates them into the general

category of whether or not they are used as food fish, and they can be further subdivided into where their depot fat is located. In addition to species, fat deposition depends upon feeding habits, season, spawning cycle, and the temperature of the water in which they live. The chemical composition depends, to a large extent, on ingested diet, which also relates back to species, since most species of fish have a fairly specific diet. Stored depot fat is normally similar to ingested fat. In general, the more the fish eats the greater its fat content. The spawning cycle influences feeding habits, since the fish normally stops eating before spawning and lives off stored fat. At this time, energy is also required to develop their rapidly maturing sex organs. This depletion of stored fat at spawning time occurs in both fish that store their fat in muscle tissue and fish that store their fat in the liver.

Fish oil can be processed like other oils and will undergo hydrolysis and saponification, hydrogenation, oxidation, sulphation and sulphurization, fractionation, and bodying of oil with heat.

Fish in general contain oil of which approximately 25% is saturated and 75% is unsaturated (usually highly unsaturated); the composition of fish oils can be found in Table 11.6. The quantity of unsaponifiables is extremely variable in fish oils and most fish liver oil contains relatively large amounts of cholesterol ($C_{27}H_{46}O$), but body oils are relatively low in this component. In general, fish oils are more complex due to the long chain of highly unsaturated fatty acids, than are fats from animals that live on land or from vegetable fats. It is generally believed that fish oil odour is due to the high level of unsaturated fatty acids. Hydrogenation of fish fat will cause the fat to lose this odour. Fish that inhabit northern regions have a higher degree of unsaturation in their oil than fish that are caught in warmer latitudes.

Fish oils deteriorate due to the action of natural lipases in the fish tissue or from microorganisms in the fat. This generates free fatty acids, causes development of oxidative rancidity of both fats and vitamins, and encourages flavour reversion. Maintaining the oil at less than 0.3% moisture will prevent bacterial growth and prevent deterioration caused by their growth and by enzymes produced by the microorganisms. Tissue that is stored as cold as possible will delay bacterial, enzymatic and chemical reactions that result in deterioration. Maintaining tissue intact rather than minced will also retard deterioration due to less contamination and more segregation of components by tissue barriers. Heating of tissue or oil to 80–100°C (176–212°F) for 15–20 minutes will inactivate the enzymes and prevent their continuing catalytic effect. Avoidance of metals which act as catalysts will also retard oxidation. Slight hydrogenation as well as the addition of antioxidants and the exclusion of air also inhibit oxidation.

Fish oil refining

Fish oil can be refined using the same techniques used with other oils, but because of the chemical nature and processing techniques, specific types of refining are popular. Most refining of fish oils consist of removal of free fatty acids, stearine (cold clearing), pigments (bleaching), and odours (deodorization). Removal of free fatty acids can be accomplished by alkaline refining, vacuum steam distillation, esterification, or solvent separation.

Alkaline refining is the most popular of these techniques. It neutralizes the free fatty acid with sodium hydroxide (NaOH, caustic soda) or sodium carbonate

Table 11.5 — Distribution of oil in fish

Class	Teleostomi or teleost	Selachii
Use	common food fish	Generally not used as food
Skeleton	Calcified, internal	Cartilaginous, internal
Fish	Cod,	Shark,
	flounder,	skates,
	haddock,	ray
	hake,	
	halibut,	
	herring,	
	pilchard,	
	salmon,	
	sole	
Large quantities	Liver	
of oil	cod	shark
	haddock	skate
	hake	ray
	Muscle	
	herring	shark
	pilchard	
	salmon	
	Intestine or mesentery	
	black cod	
	flounder	
	ling cod	
	red cod	
	salmon	
	sole (some)	
	eggs (at spawning)	
	salmon	

Source: Brody (1965).

($NaCO_3$, soda ash). The calculated amount of the alkali is added to the oil, which is generally stirred and heated 20–30°C (68–95°F) for NaOH and 90°C (176°F) for $NaCO_3$, is enough for the alkali to react with the free fatty acids, but insufficient to saponify the oil. The oil and soap stock is allowed to separate, sometimes with the aid of a salt brine. The oil is washed several times with hot water. The absorbing properties of soap will usually also remove some of the pigments and dispersed proteinaceous particles. Centrifuging and/or filter-acids and filtering are usually also helpful in separating these two fractions.

Vacuum-steam distillation is primarily useful in deodorization, but also some of the free fatty acids are removed. The minimum practical level is approximately 0.25% free fatty acids, which may be sufficient for some uses.

Esterification is the reaction of the free fatty acids with an alcohol. If there are

Table 11.6 — Range of percentage distribution of fatty acids in fish oils

	Percentage of fatty acids				
	Liver		Muscle	Viceral	Eggs
	Teleostomi	Selachi			
Unsaponified (%)	0.8–8.0	0.3–80.0	0.7–2.1	0.75	7.2–8.8
Saturated					
C14	0.30–7.6	1.2–7.4	3.4–7.0	5.8	2.3–3.1
C16	6.5–19.2	8.4–17.0	11.3–18.6	15.7	12.9–16.0
C18	0–8.9	0–7.2	0.8–3.5	2.0	0.5–2.2
C20	—	0–3.6	—	—	—
C22	—	0–3.2	—	—	—
C24	—	0–0.4	—	—	—
Unsaturated[a]					
C14	0–1.5 (2.0)	0–1.7 (2.0)	0.1–1.2 (2.0)	1.4 (2.0)	0.1 (2.0)
C16	3.4–21.4 (2.0–2.5)	2.5–12.6 (2.0–2.2)	6.2–15.5 (2.0–2.7)	10.5 (2.5)	9.6–12.6 (2.0)
C18	20.0–39.6 (2.0–3.0)	12.8–50.6 (2.0–3.4)	17.7–30.0 (2.7–4.0)	31.8 (2.6)	23.7–34.8 (2.7–4.0)
C20	3.5–31.5 (4.1–7.1)	10.6–32.5 (2.0–7.3)	17.9–26.6 (4.1–10.0)	22.4 (7.1)	23.2–27.2 (7.6–8.0)
C22	6.9–18.1 (4.4–10.0)	7.9–30.5 (2.1–10.5)	12.0–21.9 (4.3–10.0)	9.3 (10.5)	15.0–16.8 (10.4–11.2)
C24	—	0–12.0 (2.0–5.9)	0.1–15.2 (3.8–10.9)	—	—

[a](value) is the average unsaturation for individual species of fish in terms of –H.
Source: Baily (1952).

short chain alcohols, such as methyl or ethyl, their esters may be removed by vacuum (or steam) distillation, but if polyhydroxy alcohols such as glycerol are present, the esters may satisfactorily remain within the fat.

Solvent extraction with such solvents as alcohol or dilute acetone, in which free fatty acids are more soluble than in neutral oil, can also be used to remove the free fatty acids.

Separation of the solid triglyceride from the oil when the oil is cooled is called 'cold clearing', 'winterization' or 'destearination'. This prevents the oil from clouding in cold weather or under refrigeration. This is not only desirable from a cooking oil standpoint, but is also useful in fast-drying paints.

Bleaching of oil may be accomplished by adsorption of the pigments on colloidally dispersed natural or activated clay or carbon particles; the combination is

removed by filtering. Decolourization can also be accomplished with oxidizing or reducing agents.

Deodourization of oils with fishy odours is usually accomplished by vacuum-steam distillation at high temperatures or by hydrogenation of the oil.

Fish oils are used for human use as canning oil (e.g. salmon and sardine), margarine production (usually hydrogenated), cooking fats (usually hydrogenated; not permitted in the U.S.) and shortening (not permitted in the U.S.). Fish oils are used in the medical and animal feed areas for vitamin A and D content as the natural oil, 'base oils' (carrier for vitamins), combined in a dry pre-mix or as a water dispersion of vitamins. Industry uses fish oils in the production of soaps and detergents, paints and varnishes, floor coverings and oil cloths, oiled fabrics, printing inks, rubber and lubricants, and in the processing of insecticides, alkalied resins, cosmetics, metal and processed leather.

Types of cod liver oil

There are three types of cod liver oil that vary in purity and vitamin level, and consequently are used for different purposes.

Number one oil is a light straw-coloured, medical-grade oil, which is used exclusively for pharmaceutical purposes. This oil is only obtained from fresh livers by the low-temperature (82–87°C (180–190°F)) thermal rupture of the cells with the oil allowed to ooze out. This oil is high in vitamin A potency.

Number two oil is a reddish-orange coloured oil caused by partial oxidation of the oil and is obtained by further processing of the residue after extraction of No. 1 oil. The residue is subjected to additional steaming and pressing. Because it is lower in vitamin A potency, it is used as stock feed and for industrial purposes.

Cod oil is a dark-coloured oil obtained from partially decomposed livers. It is high in free fatty acids. It competes with fish body oils and is used in the industrial area for such things as lubricating leather, tempering steel, and making printing inks, oil cloth, linoleum, paints, and varnishes.

Fish liver oils

Fish liver oil is high in vitamin A and D and for these reasons it has been used for many years for the treatment of rickets and night blindness. Vitamin A today can be produced synthetically, but by extracting the liver oil products, the vitamin D complex in addition to vitamin A is available from the press residue. The non-triglyceride fraction of fish oils will contain, as previously mentioned, vitamin A (vitamin A_1 ($C_{20}H_{30}O$), and vitamin A_2 ($C_{20}H_{28}O$)) and vitamin D (D_1 ($C_{56}H_{88}O_2$), D_2 ($C_{28}H_{44}O$) or calciferol, and D_3 ($C_{27}H_{44}O$) or activated 7-dehydrocholesterol ($C_{27}H_{44}O$)). It will also contain cholesterol (($C_{27}H_{46}O$), e.g. Atlantic cod liver oil, 0.3%), lecithin, pigments (astacin ($C_{40}H_{48}O_4$, red), fucoxanthin ($C_{42}H_{58}O_6$, yellow), xanthophyll ($C_{40}H_{56}O_2$, yellow), carotene ($C_{40}H_{56}$, red to purple), taraxanthin, zeaxanthin ($C_{40}H_{56}O_2$, yellow), and chlorophyll ($C_{54-55}H_{70-72}MgN_4O_{5-6}$, green)), monoglyceride esters, and hydrocarbons (squalene, $C_{30}H_5$).

The water-soluble vitamins, including the B-complex, are often obtained from the press-liquor coming from the fish meal manufacturing process, in which whole fish are utilized. The press-liquor is centrifuged and treated with 0.25%–0.5% alum

($AlKO_8S_2$) to precipitate the proteins. The clear liquor is evaporated under vacuum or may be acidified or treated with a solid absorbant which absorbs the vitamins. The vitamins are removed from the absorbant with a solvent, which is later removed by evaporation.

Due to the differing composition of fish livers, extraction procedures often vary; a classification of fish livers and viscera and extraction techniques may be found in Table 11.7.

The high-oil, low-vitamin A potency livers do not justify an expensive extraction procedure. The high fat level also acts as a solvent for the vitamin A and helps with its extraction.

The simplest and most economical technique is direct steaming at 85–88°C 185–192°F (some procedures call for 70–75°C (158–167°F)), which thermally ruptures the tissue. The oil is then skimmed and filtered or centrifuged from the water fraction. With fresh liver, this technique produces good-quality oil, but stale livers result in a high fatty acid level. Yields of only 70–75% are often obtained.

A simple percolator can also be used to extract the livers with steam. A 5-hour extraction will yield approximately 80% of the oil in the liver.

The fish livers can also be cold extracted by grinding the fish livers and removal of approximately 80% of the oil from the raw livers with a centrifuge.

A flotation technique is also available in which the livers are treated with a preservative (2% formaldehyde (CH_2O), phenol (C_6H_6O), resorcinol ($C_{12}H_9O_2$ NaO_5S), cresol ($C_8H_{10}O_2$) or alcohol (C_2H_6O) mixed with a base such as hydrate of sodium carbonate (Na_2CO_3 in H_2O) to yield a pH of nine) that also coagulates the liver protein and inactivates the enzymes. The denatured material is next ground and mixed with water and allowed to separate. The extracted material is then vacuum-dried to dehydrate it and to coagulate any extracted protein, which is removed by filtering. The filtered fraction is then chilled to 0°C (32°F) to remove the solidified stearic acid by re-filtering.

Oil can also be separated from fish liver by adding calcium chloride ($CaCl_2$) to coagulate the protein, which releases approximately 50% of the oil.

To accelerate oil extraction time, with most extraction procedures, fish livers can be vacuum cooked at a reduced (compared to non-vacuum) temperature and this procedure will also increase the yield of oil.

Liver oil can also be removed by freezing the fish livers and pressing out the oil from the frozen liver.

Dehydration of liver can also be used as a technique to separate the oil. In this technique the disintegrated livers are mixed with dry beet pulp or dehydrated cereal grain pulp which coagulates the protein. The oil is then removed from the dehydrated livers by cold pressing.

In the fish livers classified as low-oil high-vitamin A potency, the oil is more tightly held to the protein and steaming techniques are not sufficient to break this combination. In this case, it is usually necessary to digest or solubilize the protein in order to release the oil. Alkali digestion can be used to release the oil. The livers are first ground and then 1–2% sodium hydroxide (NaOH) or 2–5% sodium carbonate (Na_2CO_3) is added. The proper quantity of alkali is important or saponification may occur and vitamin A absorption in the soap may take place. The mixture is stirred and cooked with steam at 82–87°C (180–190°F) and then the oil is removed by centrifuging.

Table 11.7 — Classification of fish livers and viscera

Type	Fish	Liver contains	Extraction
High oil content, Low vitamin A	Cod, greyfish, haddock, hake.	50–75% oil, 500–20 000 U.S.P. units of vitamin A	Steam, percolator, cold extraction, flotation, vacuum cooking, freezing, dehydration.
Low oil content, High vitamin A	Halibut, ling cod rockfish, sablefish, tuna.	4–28% oil, 25 000–600 000 U.S.P. units of vitamin A	Alkali digestion, enzyme and alkali digestion, acid digestion, solvent extraction, extraction with low vitamin A oil.
High oil content , High vitamin A	Basking shark is low in vitamin A; hammerhead shark is high in vitamin A;	30–75% oil, 0–340 000 U.S.P. units of vitamin A	Extraction by many of the above procedures depending on composition.
	Soup fin sharks: female low in vitamin A, male high in vitamin A.	45–75% oil, 20 000–200 000 U.S.P. units of vitamin A.	
Viscera, low oil content, high vitamin A	Black cod, halibut, ling cod, rockfish, swordfish.	2–15% oil, 2000–700,000 U.S.P. units of vitamin A.	Extraction with low vitamin A oil, solvent extraction

Source: Brody (1965).

Another alkaline digestion technique places the fish livers in 82°C (180°F) water and a sufficient quantity of sodium hydroxide is added to neutralize the free fatty acids. The mixture is stirred for one hour at 90°C (194°F) and the oil is separated with three volumes of 5% saline solution. The extracting mixture is next washed, heated to 75°C (167°F) and centrifuged.

An additional alkaline technique involves grinding the livers and digesting them at a pH of 8.5–12.5 with either borax ($B_4Na_4O_7$) or ammonium hydroxide (NH_3 in H_2O) or trisodium phosphate (Na_3PO_4) at a temperature of 76–79°C (170–175°F) for 15–20 minutes. The oil is then separated by centrifuging.

A combination of enzyme and alkaline digestion can also be utilized to remove the oil from the fish livers. The livers are ground and diluted with an equal volume of water, the pH is adjusted with 25% sodium hydroxide (NaOH) and 0.05% commercial pepsin is also added. The temperature is maintained at 43–48°C (110–120°F) for 35–48 hours. After hydrolysis, the pH is re-adjusted to 9 with sodium carbonate (Na_2CO_3) and the alkaline digestion continues for one hour at 79°C (175°F). The oil is then separated by centrifugation.

Acid digestion can also be utilized to separate the oil from fish liver. The livers are ground and the pH is adjusted to 1.5 with acid and the mixture is then cooked and stirred. The oil is separated by centrifugation.

Solvent extraction can also be used to separate the oil from fish livers. The extraction is normally preceeded by disintegration of the liver and removal of moisture. Other preliminary procedures might include steaming at 70–75°C (158–167°F) for 30–45 minutes, or heating or treating with acetic acid ($C_2H_4O_2$) to denature the liver proteins. Solvents often used include acetone (C_3H_6O), benzene (C_6H_6), carbon disulphide (CS_2), carbon tetrachloride (CCl_4) , dioxane ($C_4H_8O_2$), ethylene dichloride ($C_2H_4Cl_2$), ethyl ether ($C_4H_{10}O$), light petroleum, or trichloroethylene (C_2HCl_3; most popular). The solvent extract is then filtered, sometimes washed, and the solvent is removed by vacuum distillation. Oxidation imparts a reddish colour. A reduction in vitamin A potency is often a problem with solvent extraction, particularly if prolonged heating or elevated temperatures are used.

The high-oil high-vitamin A content fish liver have a tremendous variation in vitamin A as well as oil content and the extraction procedure for an individual species, and sometimes sex, depends on this composition. The appropriate extraction procedure can often be found in the previously mentioned procedures or a combination of them.

Extraction of fish livers low in oil content (e.g.salmon) is often accomplished by mincing the livers with a low vitamin content oil (e.g. grayfish liver or pilchard oil) and heating at 100°C (212°F) for 30–60 minutes. The added oil acts as a solvent for some of the liver oil and vitamins. The oil is then separated by settling or centrifuging.

The viscera of some fish, even though low in oil are high in vitamin A content. It is usually extracted by removal of the stomach, liver, milt, or roe and the remaining viscera are ground and alkali-digested. The digested material is repeatedly washed in a 'pickup oil' (e.g. herring oil), which is low in vitamin A, and then centrifuged.

Vitamin A and D concentrates from fish liver oil are manufactured by saponification and then non-polar solvent extraction of the vitamins (both A and D). The solvent is then removed by distillation.

Another technique used to concentrate the vitamins is short-path distillation, which requires a high vacuum (0.001 mm mercury). A thin film of oil is heated and the vitamin concentrate distills off and is condensed on a cooled surface. Using this technique, vitamins A and D can be separately removed from the oil. Another technique involves absorption of the vitamin: after conversion to an alcohol by

methanolysis, it is separated from the methyl esters of fatty acid by absorption on alumina or silicic acid. In other techniques, it is absorbed on soap. Impurities of the vitamin concentrate are often absorbed on weakened acid clay.

Fish liver oils should be protected against oxidation of vitamin A and the unsaturated fatty acids by storage in a cool place, in a clean, dry, airtight drum, with a minimum of headspace, which is filled with nitrogen or carbon dioxide. Some processors put a tin or enamel coat on the inside of the drums. The oil should also contain less than 0.3% moisture or sediment (other than stearine or waxes) and be free of proteins. Oil should also be protected from light.

FISH LIVER PRESERVATION

Livers can spoil due to rancidity, enzymic degeneration and fermentation, or putrefaction due to microorganisms. Fish liver may be handled fresh, but they are very vulnerable to bacterial action and lipolytic action. Packing in ice can be used for only a short duration of storage.

Freezing with exclusion of oxygen is the best way of preserving fish liver, but often the thawing of the liver leads to rupture of the liver cells, which are even more vulnerable to microbial, biochemical and chemical deterioration than before freezing.

A 10% good-grade salt (NaCl) or a 0.25% formalin (CH_2O in water) addition can be used, but this coagulates the tissue and makes the liver more difficult to process. A combination of germicide and base (previously discussed) can also be used. Mixing 9 parts of soda ash (Na_2CO_3) with 1 part of sodium nitrate ($NaNO_3$) and solubilizing this mixture in an equal volume of water and then adding 5% of this solution to the liver can also be used as a preservative.

FISH GELATINE

Gelatine production is discussed in Chapter 5. Some of the differences in land animal and fish gelatine will be discussed in this section.

Fish skin and fish bones are the source of fish gelatine. The raw fish skins are first washed for 3–4 hours in running water and then soaked in a dilute alkali solution (maximum of 0.5% sodium hydroxide, NaOH) for 6–8 hours, with three fresh solutions being used. It is next washed again in running water for 3–4 hours and is then macerated in a dilute weak acid [sulphurous acid: a solution of sulphur dioxide (SO_2) in water] with three fresh solutions being used. The skins are then washed a third time with running water. The skins are now ready to be extracted, concentrated and dried in the normal manner. One technique that is often used is to add 2 parts of water to each part of pre-treated material and then extract the gelatine at 70–80°C (158–176°F) for two consecutive 30-minute periods.

Gelatine obtained from fish does not have as good gelling properties as land-animal gelatine, but can often be used advantageously in coastal countries that have a very small animal population. Both land animal and fish gelatine can produce high-strength glue, be made sensitive to light for use in the photographic process, or applied to almost any surface to give a photographically active coating.

Isinglass is made from the air bladder, sound bladder, or swimming bladder of

fish, which can be used to produce an excellent-grade fish gelatine or glue. This bladder is located in the abdominal cavity below the vertebral column and consists of several membranous layers, which are fibrous and rich in collagen.

After removal, during the dressing operation, the air bladders are usually temporarily preserved by salting. They are then washed and air-dried for longer preservation. Examples of yields of isinglass may be found in Table 11.8.

Table 11.8 — Isinglass yields

Fish	Pounds of dry isinglass per ton of fish	Percentage gelatin from dry isinglass	Quality
Hake	45	85	Best
Cod	18	50	Poorer

Source: Brody (1965).

The air bladders are next softened by immersing in water for several hours, and later are rolled between iron rollers to convert the isinglass into 3–6 mm ($\frac{1}{8}$–$\frac{1}{4}$ in) thin strips or sheets. The sheets are further compressed by ribbon rollers into $\frac{1}{64}$ in thick ribbons that are dried and rolled into coils.

Leaf isinglass is made by immersing the bladders in warm water and they are then opened and air-dried. Book-isinglass is produced by folding the swim bladders and covering with a damp cloth.

A 2% solution of isinglass will produce a firm gel. It will dissolve in diluted acid or in alkali, but is insoluble in alcohol. In hot water, it swells and produces a characteristic fibrous structure that is not present in other gelatine.

Isinglass is used as a clarifying agent for such foods as cider, wine, beer, and vinegar.

FISH GLUE

The market for fish glue shrank considerably in recent years due to competition from new types of adhesives. Fish glue is discussed in Chapter 5. Some of the differences between glue derived from fish and glue derived from other animal products will be discussed in this chapter.

Raw materials for fish glue are fish skins and fish heads. Fish skins can be salted for short-term preservation, but should be dried for longer-term storage. Fish heads must be used fresh. Glues made from heads are inferior to those made from skins.

For manufacturing glue from fish skins, the salted skins are first cooled for 12 hours (fresh skins, 1–2 hours) in cold running water using a roller mill. This reduces the chloride content to less than 0.1%, which is necessary to prevent the finished glue from being hygroscopic (readily accepting moisture). After washing, the skins are treated with 0.2% caustic soda (NaOH) or saturated lime (CaO), then this alkali is neutralized with 0.2% hydrochloric acid (HCl), and finally the fish skins are rinsed in cold running water.

The pumped washed stock is next combined with an equal weight of water into which steam is injected. Addition of 1.9 l (0.5 gallon) of glacial acetic acid ($C_2H_4O_2$) during cooking will increase the clarity of the glue.

The 'first run' cooking is for approximately 8 hours and the diluted glue liquor is strained. The stock is then recombined with water and a 'second run' cook is accomplished at a higher cooking temperature, which produces a weaker adhesive. Often, a 'third run' is also cooked. The skin residue is then dried and used as animal feed or fertilizer. The dried residue contains 50% proteins, and, if made from fish heads, contains tricalcium phosphate ($Ca_3(PO_4)_2$).

The glue is either chemically preserved at this time or, more usually, continuously processed. The next step in processing is evaporation in an open pan, or more properly in a vacuum concentrator. The glue is concentrated until it contains approximately 50–55% solids. After concentration, small amounts of volatile essential oils, such as oil of sassafras or oil of wintergreen, are added to mask the fishy odour and to act also as a preservative.

Fish heads are processed slightly differently from skins. The heads are usually processed fresh rather than salted. Bleaching agents such as sulphurous acid (sulphur dioxide in water) or sodium bisulphite ($HNaO_3S$) are added. Aso, 1–2 gallons of glacial acetic acid ($C_2H_4O_2$) are used per ton of stock during cooking as well as larger amounts of preservatives and essential oils. Successful attempts have been made to reduce salt content by dialysis and electrodialysis.

The quality of the glue is usually evaluated by determining viscosity, gel point, moisture, speed of set, drying and hygroscopicity, and by the shear test. If proper concentration has taken place, the glue should weigh 1.17 kg/l (9.75 lb/gallon).

The advantages of fish glue are that it needs no further preparation, it is ready for immediate application, and it can be used from the same container for several days. Fish glue sets more slowly than animal glue, giving the operator time to adjust the joint. This slow setting time allows the glue to penetrate the wood better and produces greater adhesion.

LEATHER FROM FISH SKINS

Skin from aquatic animals can be converted into leather using much the same techniques (see Chapter 4) that are applied to land animals. The major difference is the external covering of animals that needs to be removed, and the normally smaller size of the finished product. Aquatic animals that have been proposed for leather production can be found in Table 11.9.

Land animals often have their hair removed in the tanning operation and aquatic animals often need to have their scales or shagreen (calcareous deposit on sharkskin) removed. Normally the skins are soaked and the scales removed mechanically by cutting them off at the roots, which leaves only the scale pattern and thus eliminates the raspy surface which is present on many fish-type skins. Shagreen is now removed chemically since scraping often damages the skin. Because of the shagreen removal procedure, chrome tannage cannot be used on sharkskin.

The tanning procedure, except for the previously mentioned exception, is very similar to the one used for land-type animals and consists of the removal of scales or shagreen, leaching out of salt, treating skins with sodium carbonate (Na_2CO_3) to

Table 11.9 — Aquatic animals that could be used for leather production

Animal	Usage
Alligator	Used for many years
Dolphin	Could be utilized
Ground fish	Neglected
Cod	
Cusk	
Haddock	
Hake	
Pollack	
Porpoise	Could be utilized
Ray	Could be utilized
Salmon	Utilized to some extent for shoes
Seal	Used for many years
Shark	Used for many years for shoes
Skate	Could be utilized
Walrus	Slightly utilized

Source: Brody (1965).

saponify small amounts of fat remaining in the skin, bating the skin, and tanning by either the vegetable procedure (most popular) or the chrome procedure (not used if shagreen is removed chemically).

In general, fish skins produce a smooth, flexible, fine-textured, durable, strong, long-wearing, non-scuffing, naturally and variably patterned leather which has porosity and comfort against the foot. The leather can be cleaned with good polish and it maintains its original colours well.

Fish skins are not responsible for a large share of the leather market because they have trouble competing economically with synthetics and leather from land animals (Brody, 1965).

A great many types of leather could be produced from aquatic animals due to the wide variety of possible species of skins, types of tanning, colouring types and concentrations used, exposure times, and types of chemical reagents utilized.

CHITIN AND CHITOSAN

Chitin and chitosan are primarily acetylated polymers of glucosamine which have basic (high pH) characteristics. Chitosan is a collective term applied to deacetylated chitins in various stages of deacetylation and depolymerization. Chitosan is primarily an aliphatic polyamine. The polysaccharide chitin is found in a wide variety of animal species (see Table 11.10) and, in fact, is the second most abundant organic substance on earth after cellulose. Chitin production is primarily from shellfish waste. The immediate principal source is shrimp and crab waste.

Approximately 65% of whole clams and 85% by weight of whole oysters consists

of shells, and the shells contain 3–6% chitin. Currently, the shells are used for soil liming, animal feed additives and road building, but they could be used for chitin extraction. Processing, however, is a challenge due to the large amount of minerals (85–90%) in the shells. The minerals are removed by acetic acid and then extraction continues normally.

The backbone or pen of squid is one of the purer forms of chitin, but it accounts for only 1% of the squid's body weight. On a dry-weight basis, it contains 40% chitin. The demineralization step can be eliminated since it is free of calcium salts.

Table 11.10 — Percentage chitin on dry-weight basis in processing waste

Origin of waste	Chitin (%)	
Clams/oysters	3–6	
Fungi	10–25	
Insects	0–8	
Krill	3–7	24% in non-tail
Shellfish	14–35	25% average
Squid	1–2	40% in backbone

The manufacture of chitosan from the exoskeletons of crustaceans involves demineralization with dilute acid, deproteinization with dilute alkali at a moderate temperature to purify chitin, and deacetylation with concentrated alkali at a high temperature to convert chitin to chitosan. Variation in reagents, concentrations, time and temperature will determine the chemical characteristics and molecular weight distribution of chitosan. An extracellular chitinase enzyme of microbial origin has also been used to hydrolyse chitin waste into smaller sugar units which can be used in animal and aquaculture feed. Other research has shown that the enzymatic hydrolysate of chitin can be converted into a single cell protein by yeast.

The uses and proposed uses of chitin and chitosan can be outlined as follows:
Uses of chitin:

(1) Paper and textile additives and finishes.
(2) Food wrapping film and speciality filaments.
(3) Absorbents for metal ions
(4) Cements for leather
(5) Drilling muds
(6) Photographic products
(7) Coagulants useful for flocculating suspensions.
(8) Wound-healing activity
(9) To produce yeast single-cell protein

Uses of chitosan:

(1) Biodegradable and, therefore, food-processing waste coagulated with it can be fed to animals
(2) Dewatering of sludge
(3) Water purification
(4) Ion-exchange
(5) Chelating solids for chromatography
(6) Tough, flexible films
(7) Wound-healing promotion
(8) Adhesives
(9) Ion-exchange membranes
(10) Laundry-shrinkage control

Processing of various marine animals for chitin and chitosen has many common features. Krill will be described here in more detail as an example (see Fig. 11.5). Processing of Antarctic krill starts by mechanical peeling which results in 14.9% non-tail processing waste which contains 24% chitin, 8.6% nitrogen, 41% protein, 11.6% lipids and 23% ash on a dry-weight basis. The deproteinization is accomplished by extraction (1 part solid to 10 parts of solvent) with 3.5% NaOH at 90–95°C for two hours. Demineralization is accomplished by extraction (1 part solid to 22 parts solvent) of the NaOH extracted waste with 0.6 N HCl at 20°C (68°F) for 2 hours.

In some procedures the demineralized protein is further treated by enzymatic hydrolysis. Yeast may then be grown on this product to produce single-cell protein.

PEARL ESSENCE

Quanin is an irridescent substance found in the epidermal layer and on the scales of fish species that swim near the surface of the water (e.g. herring and mackerel). It is often isolated and used to coat objects in order to give them a lustrous effect. The crystalline quanin is much easier to recover from the scales than it is from the epidermis. A suspension of crystalline quanin in a solvent is called 'pearl essence'. When quanin is deposited on the inside of hollow beads or coated on the surface of solid beads, it produces an optical effect similar to real pearls. Pearl essence and pearls are, in fact, totally different chemically and are produced by different animals. This material is also used to coat objects other than beads where iridescence is desired.

Pearl essence can be obtained from the scales of many pelagic fish. Many that are used commercially are given in Table 11.11.

The scales are preserved by placing them in a 10–15% brine, which is later drained. The scales are then squeezed and compressed and then the scales can be stored for several weeks at 0°C (32°F). The pearl essence is collected by washing and scrubbing the quanin from the scales with a large agitator similar to a domestic washing machine. Sometimes kerosene (C_{10} to C_{16}) is used as the washing medium. The pearl essence material is then separated from the wash material with the use of a centrifuge. To purify the quanin, protein contaminates may be degraded with pepsin in an acid medium at 25–30°C (77–86°F) for 50 hours. Fat is removed by a non-polar (e.g. benzene (C_6H_6) or ether ($C_4H_{10}O$)) solvent. The crystalline quanin is separated by centrifugal force from the solvent. It is then suspended in either an aqueous or a non-aqueous liquid.

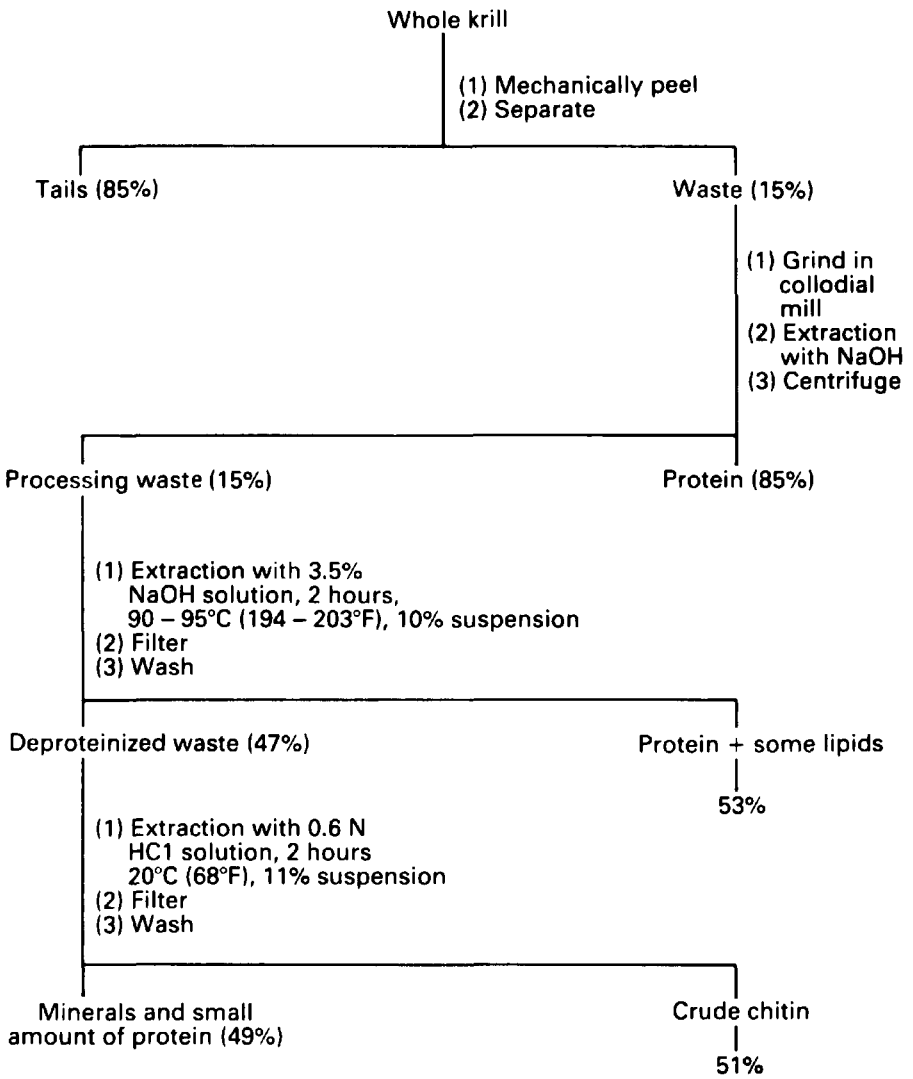


Fig. 11.5 — Processing of krill for chitin. From Anderson *et al.* (1977).

For aqueous suspension, the scales are washed with water to which some ammonia (NH_3) has been added. The extract is strained and then the quanin is allowed to settle. The supernatant is decanted and replaced with fresh ammoniated water. This procedure is repeated several times until the product is purified. To this suspension, 0.3% salicylic acid ($C_7H_6O_3$) and adhesives of animal or fish origin may be added.

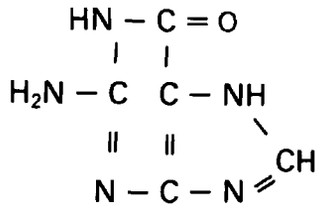
For non-aqueous suspensions or lacquers, such organic solvents as amyl acetate ($C_7O_2H_{14}$), ethyl acetate ($C_4H_8O_2$), acetone (C_3H_6O), acetic anhydride ($C_4H_6O_3$), chloroform ($CHCl_3$), carbon tetrachloride (CCl_4), acetic acid ($C_2H_4O_2$) or the pearl essence may be suspended in a highly concentrated form in a viscous lacquer of celluloid in amyl acetate.

The chemical properties of quanine places it in the category of a nucleoprotein found in nucleic acid. It has the following structural formula:

Table 11.11 — Sources of pearl essence.

Area	Fish scales used
California	Pilchard, sardine
Florida, fresh water	Gizzard, shad
Great Lakes	Cisco, whitefish
Maine	Sardine herring
Mississippi Valley	Silver carp
Pacific coast	Alaskan herring, Atlantic menhaden, salmon, southern mullet
Other areas	Barracuda, bonito, butterfish, mackerel, mullet, shad

Source: Brody (1965).



USE OF SHELLS

Shells have been used to raise the pH of agricultural soil (liming), and as a feed additive to add calcium and other minerals to animals diets and to build roads. Equal parts of oyster shells, lime (CaO; also obtained from shells), sand and water have been used for many years in coastal areas to make a type of concrete (tabby) used for building and seawall construction. Lime needed for hardening the mixture is extracted from the shells by burning them with pine logs in a kiln. Ashes left from the logs give tabby its grey colour. This coastal concrete is very durable, with many of the structures lasting for hundreds of years.

In the early 1900s, unionid shells were used extensively in the button industry. Today, macreous spheres are cut from unionid shells and are embedded into the tissue of Japanese pearl oysters. These comprise 90% of the marketable pearl.

FERTILIZER FROM FISH

It has been recognized for a long time that fish products would increase the growth of plant material. The North American Indians increased their corn yield by planting a fish in every hill of corn.

Crawfish waste applied at the rate of 6283 to 11 210 kg/ha (5000 to 10 000 lb/acre) can be used to supply calcium, nitrogen, phosphorus and other elements essential to plant growth. Since these elements are in the organic form, they have the advantage

of being released over a longer period of time than most commercial fertilizer sources. Crawfish waste increases the soil calcium level and acts as a liming agent by raising the soil pH.

Fish offal or trash fish can be converted to plant fertilizer by digesting them with sulphuric acid (H_2SO_4). The treatment reduces the fish odour, converts protein into ammonium sulphate ($H_8N_2O_4S$) and makes the bone phosphate absorbable by plants. Another process solubilizes the fish products with urea (CH_4N_2O). This fish–urea blend has a reduced fish odour, and the urea is immediately available to plants as a source of nitrogen. The fish proteins are still in their original protein or proteose state and must undergo several hydrolytic changes by soil bacteria to become available for plant use. Therefore, these proteins are absorbed by plants at a slower rate than are inorganic fertilizers.

REFERENCES

Anderson, C. G., de Pablo, N. and Romo, C. R. (1977) Antarctic krill (*Euphausia superba*) as a source of chitin and chitosan. *Proceedings of the First International Conference on Chitin and Chitosan.* pp. 54–63. M.I.T., Cambridge, Mass.

Anon (1945) *Guide to commercial shark fishing in the Caribbean area.* U.S. Fish and Wildlife Service, Fishery Leaflet 135.

Bailey, B. E. (1952) *Marine oil with particular reference to those of Canada.* Fisheries Research Board Con. Bulletin No. 89, Ottawa.

Brody, J. (1965) *Fishery by-products technology.* Westport, Connecticut, AVI.

Connell, J. J. and Hardy, R. (1982) *Trends in fish utilization.* Farnham, England, Fishing Books.

Gillies, M. T. (1975) *Fish and shellfish processing.* Park Ridge, New Jersey, Noyes Data Corporation.

Lee, C. M. (1984) Surimi process technology. *Food Tech.* **38** (11) 69–80.

Nilson, H. W. (1950) *Feeding value of fish meals.* U.S. Fish and Wildlife Service, September No. 269. Washington DC.

Ockerman, H. W. and Stombaugh, I. (1987) Science and super foods for the world's hungry. Accepted for publication in *Science of Food and Agriculture,* CAST, Iowa.

Orr, M. L. and Watt, B. K. (1957) Amino acid content of food. *Home Economics Research Report* No. 4. Washington, DC, U.S. Department of Agriculture.

Raa, J. and Gildberg, A. (1982) *Fish Silage; A Review.* CRC Critical Reviews in Food Science and Nutrition. CRC Press, Boca Raton, Florida, pp 383–419.

Tressler, D. K. and Lemon, J. Mcw. (1951) *Marine products of commerce,* p 712. Reinhold, New York.

U.S. Fish and Wildlife Service. Bureau of Commercial Fisheries. (1962) *Industrial fish products-1961, annual summary* C.F.S. No. 2863.

Windsor, M. and Barlow, S. (1981) *Introduction of fishery by-products,* Farnham, England, Fishing News Books, 187 pp.

12

Poultry by-products

POULTRY

By-products of the poultry processing industry are essentially edible tissue and bone from the carcass, inedible carcass parts that are rendered, egg shells and feathers (see Table 12.1). Poultry manure is considered as a by-product from the production phase of the industry.

Mechanical separation of meat from bone is discussed in Chapter 6. In this process, large amounts of mechanically deboned poultry residues are obtained. This residue may vary, depending on the tissue deboned and the deboning process, but an averge composition is 17% protein and 13% fat (Jackson *et al.*, 1982). The protein is primarily collagen, but as much as 20% may be sarcoplasmic and myofibrillar quality. Extraction of this protein may be accomplished with solvents such as sodium chloride (NaCl) or by alkali treatments followed by acid precipitation. One extraction procedure involves tumbling of deboning residue at a pH of 10.5 at 23°C (73°F) for 30–60 minutes. After this treatment, the liquid extract can be separated from the solid residue by centrifugal force and then the pH can be adjusted to 5.5 by adding 1 N HCl to precipitate the soluble protein. The coagulated protein can then be separated from the liquid as a protein curd by centrifuging or screening.

Poultry by-product meal is manufactured by dry or wet rendering of ground clean parts of the carcass such as condemned chickens, racks from deboning operations, head, feet, underdeveloped eggs and viscera, but excluding feathers, except in trace amounts as might occur in normal processing procedures. The material is highly abrasive due to grit from gizzards (grit is used in only a very small percentage of the chickens fed in the U.S. today) which subjects the equipment to rapid wear. Backpriming with fat is sometimes used to fluidize the material, to reduce wear and improve heat transfer. Continuous processing equipment (Anon, 1979) containing a tubular shaft fitted with vertically mounted double-walled disc and a steam jacket giving a temperature of 113–116°C (235–240°F) is used by some of the larger processors. In some operations two cookers are run in series. The product is usually first ground (often with cage mill grinders), screened (often pellet-mill whirly cleaners) through a coarse screen to remove ferrous material and then ground to a

Table 12.1 — Yield of by-products from broilers, fowl and turkeys

Material	Percentage of live weight		
	Broilers	Fowl	Turkey
Waste yield from pantry			
Offal	17.5(15–20)	17.0(17–18)	12.5
Blood	3.5(3.2–4.2)	3.0	3.5
Feathers	7.0(4.8–7.5)	7.0	7.0
Feathers, wet	22.0	20.0	14.0
Mixed (dry feathers)	28.0	*a*	23.0
Water pick up			
Offal	1.0	1.0	—
Blood	—	—	—
Feathers	15.0	13.0	7.0
Mixed	16.0	*a*	7.0
Total waste yield			
Offal	18.5	18.0	12.5
Blood	3.5	3.0	3.5
Feathers	22.0	20.0	14.0
Mixed	44.0	*a*	30.0
Water evaporated			
Offal	12.7	10.6	7.5
Blood	2.7	2.3	2.7
Feathers	16.5	14.5	8.1
Mixed	31.9	*a*	18.3
Dry product (8% Moisture)			
Offal	5.8	7.4	5.0
Blood meal	0.8	0.7	0.8
Feather meal	5.5	5.5	5.9
Mixed	12.8	*a*	11.7
Pressed product (1% fat)			
By-product meal	5.2	4.3	4.2
Grease	0.6	3.2	0.8

a No advantage to mixing prior to cooking, since fat level will require pressing prior to grinding.
From: Lortscher *et al.* (1957).

consistency between those of cornmeal and flour and then passed through a fine screen. Coarse material from the screening is returned to the grinder.

In rendering (dry) the moisture level is reduced in a separate dryer to approximately 8% and then the product is pressed to remove excess fat so usually a fat level of approximately 10% remains. A flow chart showing rendering of broiler mixed waste and of broiler offal may be found in Figs 12.1 and 12.2 respectively.

The final approximate composition of poultry by-products (NRA, 1970; Vandepopuliere, 1984) is as given in Table 12.2.

The final product is usually used in pet food because of its light colour and palatability.

FEATHERS

Feathers, a by-product of the poultry industry, may be utilized for clothing, insulation, bedding, decorations, sporting equipment, feather meal and fertilizer. Feather characteristics vary according to the species of bird, age, sex and location on the body. They are often classified (Hardy and Hardy, 1949) in the following groups:

(1) Hard feathers — stiff quills and heavy vanes.
(2) Saddle feathers — long, narrow, vaned feathers from the saddle and back of a rooster.
(3) Half fluff — vaned feathers with fluff along the lower half of the quill.
(4) Three-quarter fluff — vaned feathers with fluff along the lower three-quarters of the quill.
(5) Fluff — body feathers with firm shafts.
(6) Plumules — small down feathers with soft shafts.
(7) Down — light-weight feathers without a shaft and with a long fibre length. They are three dimensional and do not pack down.

When feathers are saved, the more important feathers of the wing and tail are removed after slaughter and before scalding, but this is not done in commercial operations in the U.S. today. The carcasses then proceed to the scalder. The scalding water temperature for chickens is normally between 53° and 58°C (127–136°F) and scalding normally requires 90–120 seconds with a slightly higher temperature (60°C (140°F)) and longer time being used for turkeys. Waterfowl carcasses are scalded in the range 60–63°C (140–145°F) for 2½ minutes, and if the feathers are not saved, they are dipped in wax at 91°C (195°F) and then into cold water. The age of ducks is also important in the ease of feather removal. When feathers are saved, they may be held for as long as 12 hours if soaked in a solution containing 6.8 kg (15 lb) of salt (NaCl), 473 ml (1 pint) hydrochloric acid (HCl) and 113 l (30 gallons) of water. The feathers are usually washed with mild soap to remove dirt and blood. If appropriate, a bleaching agent such as potassium permanganate ($KMnO_4$), hydrogen peroxide (H_2O_2) or chlorine (Cl_2) can also be utilized. Stoddard's solvent (a high flash-point gasoline) is sometimes used to remove objectionable odours. Finally the feathers are thoroughly rinsed in clean water, blow-dried to encourage fluffing, and then sorted by air currents into groups by size (weight and length). Depending upon their ultimate use, some feathers are lightly sprayed with mineral oil to replace some of the natural oils that have been removed in processing.

The use of feathers in bedding has declined because of the development of synthetic fibres and plastic foam, but good-quality bedding still uses body feathers, generally from waterfowl. Basic requirements for good bedding feathers are maximum volume when in use and minimum volume for storage. Other desirable

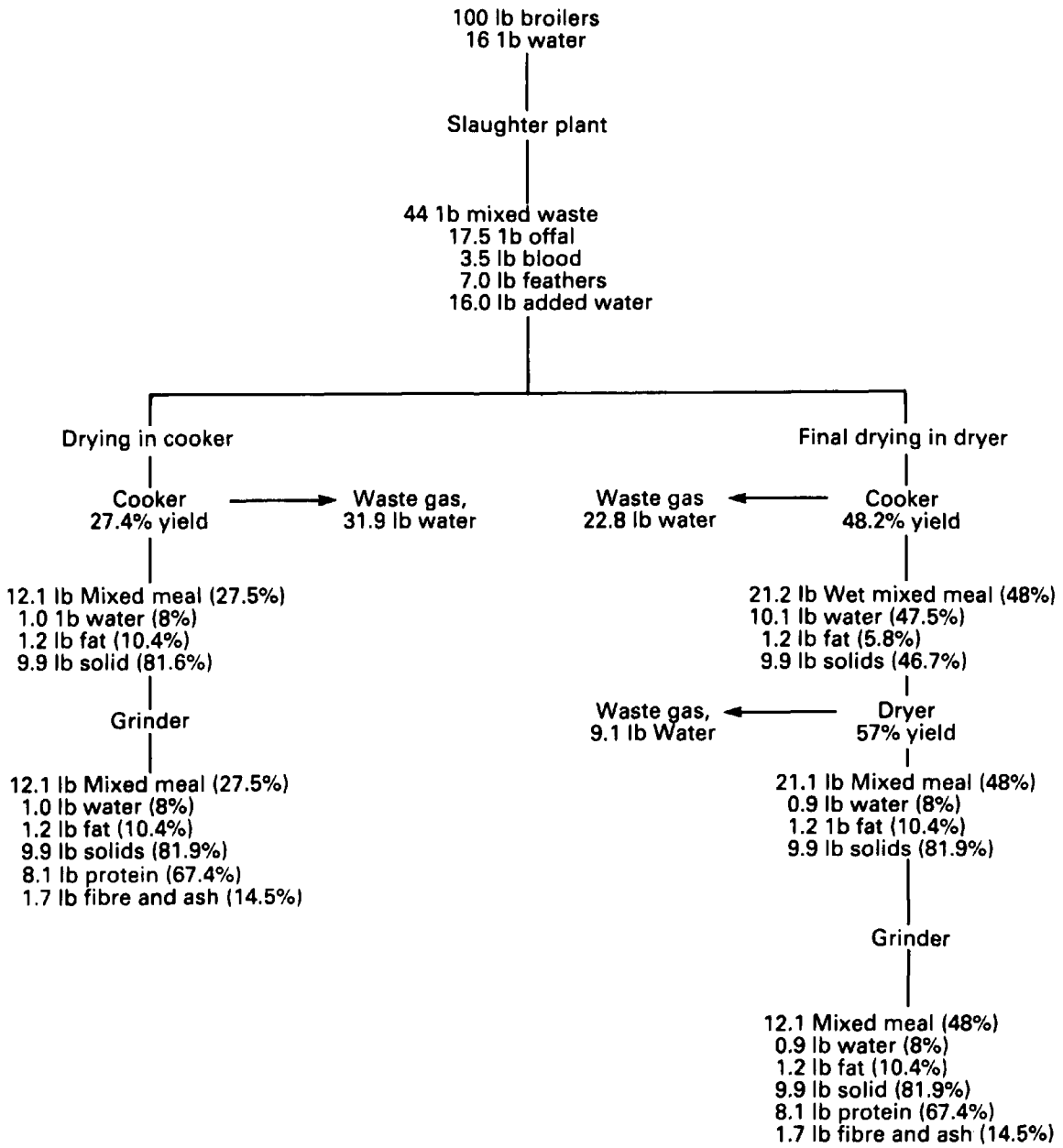
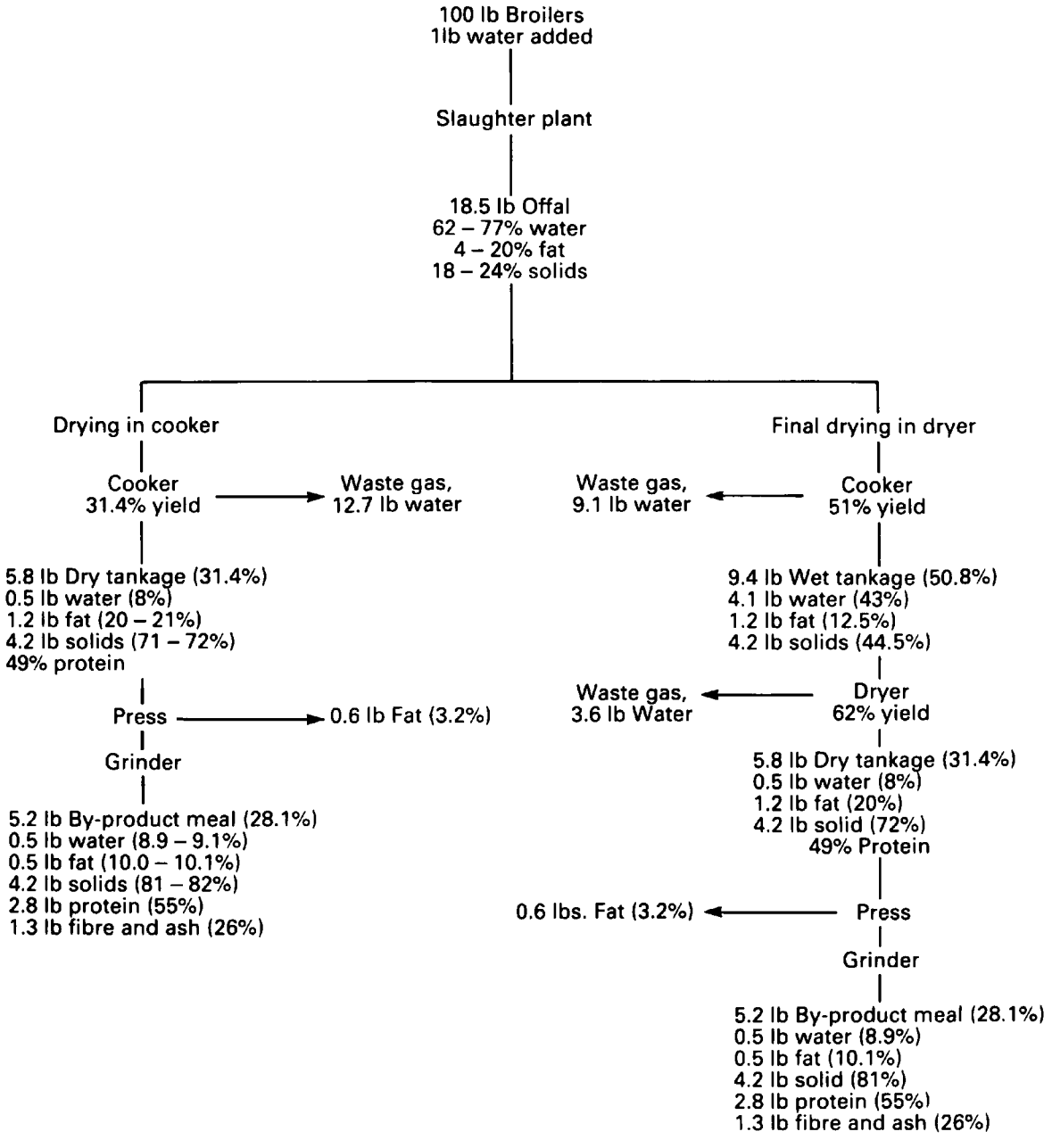


Fig. 12.1 — Broiler mixed waste by-product processing. 1 lb = 0.454 kg. From Lorchester *et al.* (1957).

characteristics include ability to return to their original volume, fluffability, low absorption, softness, drapability, warmth, cleanliness, fire-resistance, launderability and durability.

Colour, shape, size and plumage patterns are important when feathers are used for decorative purposes. For this reason, cock pheasants are in demand because of their brightly coloured feathers. In many cases the feathers are dyed, bent and trimmed to desired patterns.

For sporting equipment, feathers are carefully hand-selected. For example sturdy feathers from mature turkeys are used for fletching arrows. Feathers on an



12.2 — Broiler offal by-product processing. 1 lb = 0.454 kg.

individual arrow must all come from either the right or left wing to assure proper rotation of the arrow. Stiff feathers are also used for shuttlecocks used in badminton. Other selected feathers are used to manufacture artifical lures for fishing.

Feathers can also be used for fertilizer and mulch. They decompose slowly and gradually release their nitrogen. To prevent unwanted distribution by the wind they should be ploughed under.

The production of feather meal is the largest market of feathers. A flow chart for feather meal production may be found in Fig. 12.3.

Feathers are composed of a complex protein (keratin), which must be broken

Table 12.2 — Composition of poultry by-products

Protein	Minimum as specified
Moisture	Maximum 10%
Fibre	Maximum 4%
Ash	Maximum 15%
Acid	
Insoluble ash	maximum 4%
Fat	Maximum or minimum as specified
Grind	100% through U.S. No. 7 screen
	95% through U.S. No. 10 screen

From NRA, 1970; Vandepopuliere, 1984.

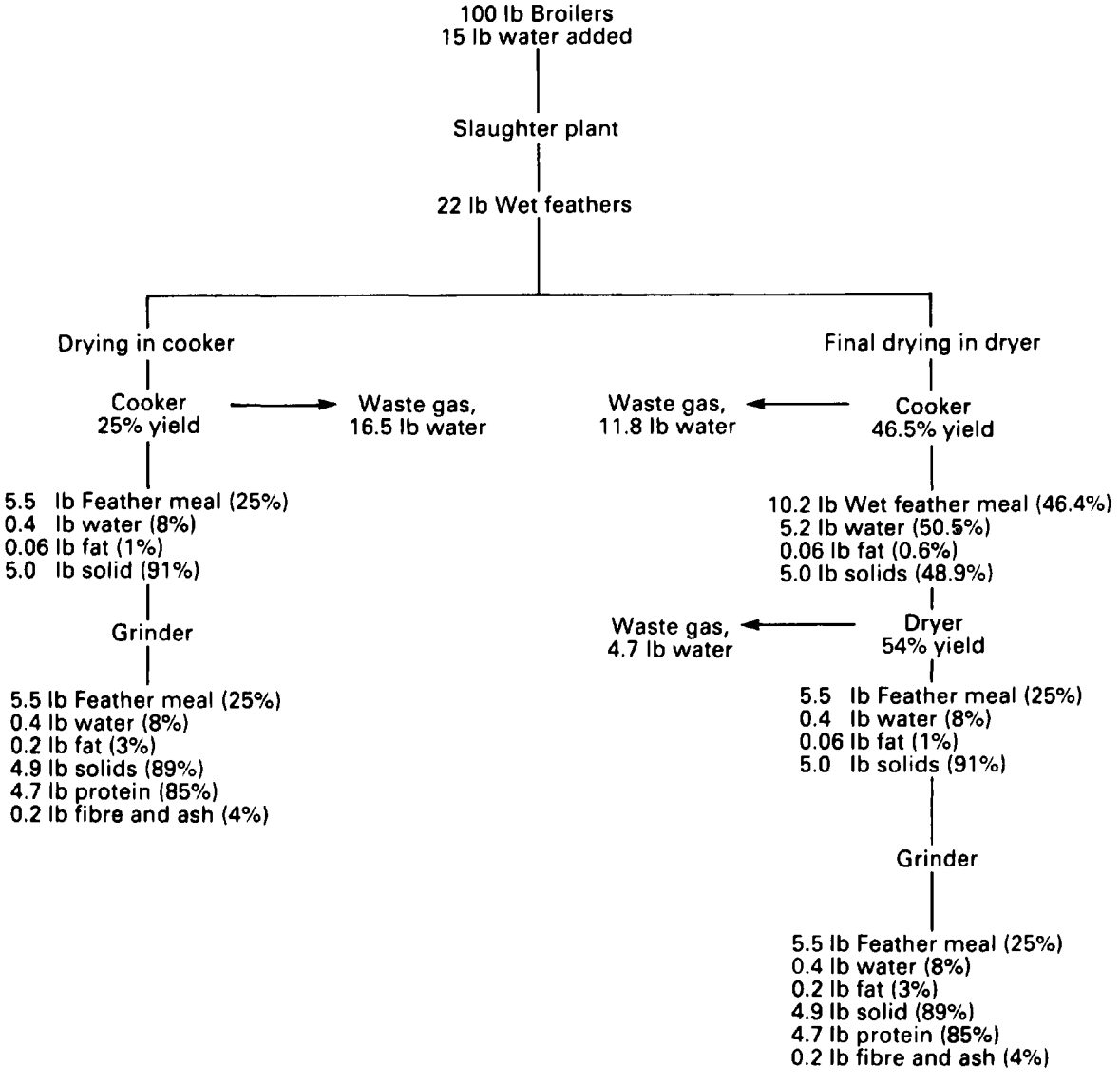


Fig. 12.3 — Broiler feather by-product processing. 1 lb = 0.454 kg. From Lortscher *et al.* (1957).

down by hydrolysis to make them digestible. After collection from a processing plant, the feathers are washed with water. In some operations they are dewatered by mechanical pressure rather than heat. After some of the water is removed, they are steamed, wet-cooked for hydrolysis under pressure with constant agitation, and then usually processed in dry-renderers (cookers) under 2–3 atmospheres pressure for 1–2 hours. The feathers are then cooled and dried, often in a tube drier that has been converted to an air drier, and then ground. The ground meal goes through a metal detector and then is screened to remove coarse particles. The digestibility of feather meal is directly affected by cooking time and pressure (amount of hydrolysis), usually with more intensive processing resulting in higher availability of amino acids and higher biological values. Feather meal (hydrolysed poultry feathers) should (NRA, 1970) be composed as shown in Table 12.3.

Table 12.3 — Composition of feather meal

Protein	75% of crude protein (range 70–80%) as digestible protein. Minimim as specified. Most contain 85–90% crude protein.
Moisture	Maximum 10%.
Fibre	Maximum 4%.
Fat	Maximum as specified.
Grind	100% through U.S. No. 7 screen 95% through U.S. No. 10 screen

From NRA, 1970.

Feather meal is rich in cystine, threonine and arginine, but is deficient in four essential amino acids; lysine, methionine, histidine and tryptophan (see Table 12.4). Therefore, when feather meal is fed to monogastric animals (poultry and swine), these amino acids need to be added to the ration. The practical level for use of feather meal in the diet is 0.5–1.5%.

Feather meal is utilized better by the ruminant animal (e.g. cattle) *in vivo* (live animal) than would be suggested by *in vivo* (test tube) tests. Utilization in the ruminant animal can be improved when the feather meal is supplemented with urea. Although feather meal can be utilized to supply half of the dietary nitrogen of ruminants, utilization is poor when excessive amounts are fed. One of the problems in processing feathers and other by-products used for feed is recontamination of the rendered product by incoming unprocessed material. The contaminated rendered product is then fed to livestock. This is a special problem with *Salmonella* organisms in poultry feeds.

EGG SHELLS

Egg shells represent approximately 11% of the total weight of an egg and are available in large quantities from egg-breaking plants and commercial hatcheries. Egg shells contain approximately 94% calcium carbonate ($CaCO_3$), 1% magnesium

Table 12.4 — Chemical analysis of feather meal

	Percentage of protein
Alanine	2.2–4.4
Arginine	4.4–8.8
Aspartic acid	3.4–6.1
Cystine	1.6–3.7
Glutamic acid	6.1–8.9
Glycine	4.2–9.0
Histidine	0.4–1.8
Isoleucine	3.0–6.2
Leucine	5.4–11.9
Lycine	0.9–2.4
Lycine, available	1.2–1.6
Methionine	0.3–0.6
Phenylalanine	3.2–7.9
Proline	6.8–14.7
Serine	7.9–12.0
Threonine	1.7–3.4
Tyrosine	1.9–3.2
Valine	4.0–10.4
Protein (%)	82.9–84.7
Ether extract (%)	1.2–2.4
Ash (%)	3.6–4.2
Pepsin, digestible	71.8–74.6

Source: Morris and Balloun (1973), Wessels (1972), McCosland and Richardson (1966).

carbonate ($MgCO_3$), 1% calcium phosphate ($CaPO_4$) and 4% organic matter (see Table 12.5). In egg-breaking plants, egg shells are centrifuged before disposal to recover adhering egg white. The inedible egg white material is used as technical albumin, usually for adhesives. Egg shells are often hauled to land-fills for disposal, but this is expensive and causes pollution problems, and the shells are susceptible to bacterial spoilage and insect infestation, resulting in offensive odours. Some progress has been made in converting the shells to human and animal feed to supply a source of calcium, especially for poultry feeds. Egg shell meal is made by drying, as soon after collection as possible, and by heating the egg shells at 80°C until they are sterilized. Processing as soon as possible after collection reduces contamination and consequently reduces the heating time required for sterilization. The processed shells are then ground into small particles. Grittiness can be partially eliminated by grinding fine enough for the product to pass through a No. 400 sieve. In addition to being a rich source of calcium, egg shell meal also has the added nutritional value of the protein from the albumin residue, egg shell membrane and the egg shell matrix. When used in human food, levels of up to 0.4% have been incorporated into mixes without affecting palatability or cooking quality. The calcium level in poultry rations

Table 12.5 — Composition (dry-weight basis) of egg shell waste

	With adhering albumin (%)	Centrifuged samples (%)	Washed sampels (%)
Original moisture (wet basis)	29–35	16.2	—
Protein	7.6–8.1	5.3	5.1
Alanine	0.45	0.26	0.20
Arginine	0.56–0.57	0.38	0.37
Aspartic acid	0.83–0.87	0.52	0.45
Cystine + cysteine	0.37–0.41	0.20	0.35
Glutamic acid	1.22–1.26	0.76	0.67
Glycine	0.48–0.51	0.38	0.35
Histidine	0.25–0.30	0.24	0.20
Isoleucine	0.34	0.19	0.15
Leucine	0.57	0.32	0.25
Lysine	0.37	0.20	0.20
Methionine	0.28–0.29	0.19	0.16
Phenylalanine	0.38–0.46	0.18	0.10
Proline	0.54–0.62	0.45	0.45
Serine	0.64–0.65	0.38	0.34
Threonine	0.45–0.47	0.30	0.29
Tyrosine	0.25–0.26	0.15	0.12
Valine	0.54–0.55	0.32	0.29
Lipid	0.10–0.20	0.3	0.05
Ash	89.9–91.1	94.2	95.4
Calcium	35.1–36.4	36.7	37.3
Chlorine	0.09	—	—
Iron	0.002	0.002	0.002
Potassium	0.10–0.13	0.07	0.06
Magnesium	0.37–0.40	0.40	0.41
Sodium	0.15–0.17	0.13	0.11
Sulphur	0.09–0.19	0.09	0.04
Phosphorus	0.12	0.10	0.12
$CaCO_3$	90.9	91.9	93.1
Neutralizing power $CaCO_3$	87–89	88.0	89.0

Source: Walton *et al.* (1973), Walton and Cotterill (1972).

is important in maintaining egg shell quality. Poultry can utilize egg shells as a source of calcium more effectively than calcium from other sources. The amino acids derived from the non-shell portion of egg shell waste are also readily available and effectively utilized by poultry. Generally, however, calcium in poultry rations is supplied at lower costs from other sources.

Egg shells can also be used for fertilizer, as a source of calcium and nitrogen.

BLOOD MEAL

Poultry blood is dried and then ground and used as animal feed. A flow chart for broiler blood processing may be found in Fig. 12.4. Also see Chapter 9.

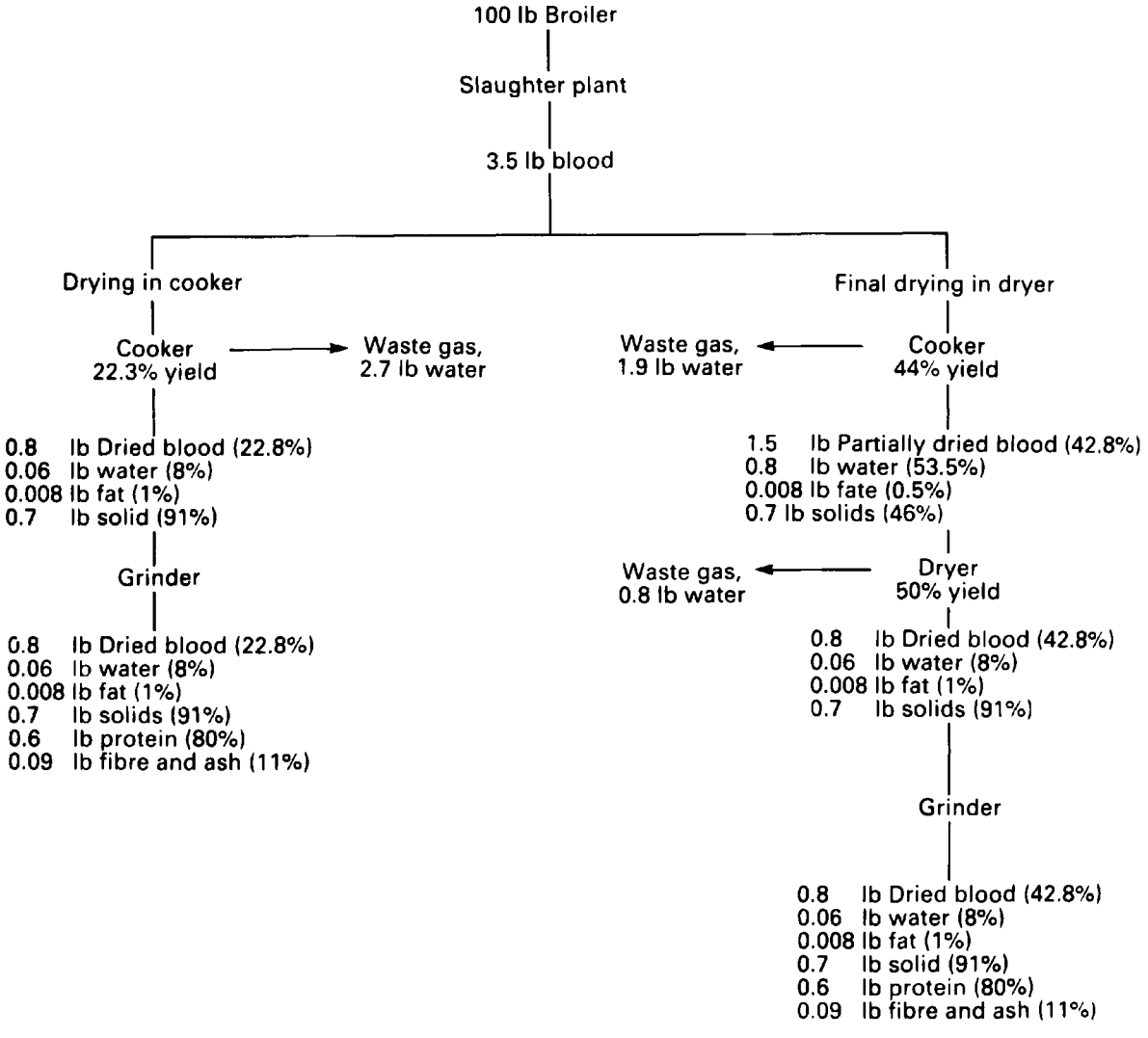


Fig. 12.4 — Broiler blood by-product processing. 1 lb = 0.454 kg. From Lortscher *et al.* (1957).

MIXED POULTRY BY-PRODUCT MEAL

Mixed poultry by-product meal is a mixture of blood, offal and feathers, in natural proportions, that have been rendered and dried. Sometimes excess fat is removed. It is used mainly for pet food. Mixed poultry by-product meal is more difficult and takes longer to process than other meals, but is better balanced nutritionally.

INEDIBLE EGGS

Inedible eggs are often used as hog (pig) feed, must be cooked before feeding to prevent spread of disease. Since shells constitute 10% of the egg, the whole egg often contains too large a proportion of calcium for balanced hog rations. For this reason, inedible eggs are sometimes broken and separated from the shells before cooking.

HATCHERY WASTE

Hatchery waste consists of infertile eggs, dead embryos, dead chickens or poults, and shells of hatched eggs. Waste from hatcheries that produce egg-laying chickens sometimes also contain male chicks that are destroyed at the time of sexing. Composition of hatchery by-product meal may be found in Table 12.6.

Table 12.6 — Percentage composition of poultry by-products

	Feather meal	Dried blood	By-products meal	Tankage	Hatchery by-product meal	
					Broiler	Egg type
Protein	75–90	75–85	50–60	45–55	—	—
(average)	85	80	55	50	22*a*	32*a*
Moisture	5–15	5–15	5–15	5–12	—	—
(average)	8	8	8	8	65	71
Fat	2–4	0.8–1.2	6–15	16–25	—	—
(average)	3	1	10	20	10*a*	18*a*
Fibre and Ash	2–7	8–14	25–30	20–25	—	—
(average)	4	11	27	22	—	—
Calcium	—	—	—	—	25*a*	17*a*
Phosphorus	—	—	—	—	0.3*a*	0.6*a*

[a] Dry basis.
From Lortscher *et al.* (1957); Vandepopuliere (1984).

POULTRY GREASE

Poultry grease is extracted from poultry offal. It is generally darker in colour and lower in grade than fat collected from beef, pork, or lamb.

POULTRY OIL

Poultry oil is oil which is removed from poultry by-product meal with a screw immediately after cooking. The removal improves the handling characteristics of the poultry by-product meal. The oil is an excellent energy source and enhances the palatability of pet food.

LABORATORY USE OF EGGS

Because viruses require living tissue for culture, embryonated eggs are sometimes the only practical media that can be used for virus culture, production of vaccines, tissue culture, toxicity or inhibiting studies or assays, embryology studies and as a medium for growth of malignant tumour cells.

MANUFACTURING USES OF EGGS

Egg albumin has been used for paints, cosmetics, ingredients in medicines, ointment, photographic supplies, ink, tanning of leather, moisturizers, soaps, shampoo, cement, artificial fibres and as an antidote for poisons.

REFERENCES

Anon (1979) World's biggest poultry renderer goes continuous. *Meat Industry*, April.

Hardy, J. J., and Hardy, T. M. P. (1949) *Feathers from domestic and wild fowl.* U. S. Department of Agriculture Circular 803.

Jackson, E. D., Consolacion, F. I., and Jelen, P. (1982) Bacteriological evaluation of alkali-extracted protein from poultry residues. J. Food Prot. **45** 797–800.

Lortscher, L. L., Sachsel, G. F., Wilkelmy, Jr, D., and Filbert, Jr, R. B. (1957). *Processing poultry by-products in poultry slaughter plants.* U.S. Department of Agriculture Marketing Research Department, No. 181.

McCosland, Mw. E. and Richardson, L. R. (1966) Methods for determining the nutritive value of feather meal. Poultry Science **45** 1231–1236.

Morris, W. C. and Balloun, S. L. (1973) Evaluation of five differently processed feather meals by nitrogen retention, net protein values, xanthine dehydrogenase activity and chemical analysis. *Poultry Science* **52** 1075–1084.

NRA (1970) *Trading rules governing purchase and sale of animal and poultry proteins.* National Renderers Association, Des Plaines, Illinois.

Vandepopuliere, J. M. (1984) *Animals as converters of by-products from animal processing.* Proceedings of an International Symposium, Wageningen, Netherlands.

Walton, H. V., Cotterill, O. J. and Vandepopuliere, J. M. (1973) Composition of shell waste from egg breaking plants. Poultry Science **52** 1836–1841.

Walton, H. V. and Cotterill, O. J. (1972). Composition of egg shell waste from egg breaking plants. *Poultry Science* **51** 1884.

Wessels, J. P. H. (1972) A study of the protein quality of different feather meals. *Poultry Science* **51** 537–541.

13

Animal processing waste disposal, reduction and utilization

A hog (pig) processor once claimed, 'We use all parts of the animal except for the squeal.' In reality, in the animal processing industry, an average of 4.5 kg (10 lb) of protein is lost to the sewer for every 454 kg (1000 lb) of live weight kill (lwk). Some animal products such as bone and blood are grossly underutilized. Much of this lost and underutilized product can be recovered and/or upgraded through in-plant pollution-reduction techniques and wiser processing of animal by-products. The process changes necessary to accomplish these tasks can provide additional profit, save/upgrade valuable protein and reduce pollution. If half of the protein now lost to the sewer were recovered there would be at least an additional 181 million kg (400 million lb) of protein each year, worth perhaps $400 million (1987 dollars) from animal processing in the U.S.A. (Hansen, 1983).

Waste characteristics and problems of disposal, etc. are similar for all aspects of animal processing, which includes seafood, poultry, and red meats. Methods for pollution reduction and upgrading of animal by-products discussed can be applied throughout the industry.

MEAT-PROCESSING WASTE CHARACTERIZATION

Meat processing waste consists of solid and liquid portions. Solids include manure and paunch manure (contents of a slaughtered animal's digestive tract) and bits of animal tissue. The liquid portion includes blood and other body fluids. In a practical sense, most of the small tissue solids and often the manure/paunch solids become mixed with water used for carcass rinsing or for clean up and are drained to the sewer as liquid waste. Blood is usually collected, especially in the larger plants, and dried for animal feed (see Chapter 9).

Four major surveys have defined meat plant raw wastewater characteristics. The results of those studies are shown in Table 13.1. Average wastewater flowrate is about 8.31 l/kg lwk (1 gallon/lb lwk). Smaller scale surveys (Steffen, 1978; Bras-

Table 13.1 — Mean values of reported meat-packing waste load characteristics per 1000 kg live weight kill (2205 lb lwk)

Survey by	BOD[a] kg (lb)	SS[a] kg (lb)	FOG[a] kg (lb)	TKN[a] kg (lb)
North Star	12.1 (26.7)	8.7 (19.2)	6.0 (13.2)	1.0 (2.2)
Mohlman	14.6 (32.2)	11.3 (24.9)	1.5 (3.5)	1.7 (3.7)
Hill	15.0 (33.1)	12.4 (27.3)	—	1.7 (3.7)
Kerrigan	11.8 (26.0)	9.0 (19.8)	8.2 (18.1)	0.9 (2.0)
Average	13.3 (29.3)	10.3 (22.7)	5.2 (11.5)	1.3 (2.9)

[a]Abbreviations are defined in the text.
Source: Hansen, 1980

ington, 1978; Berthouex *et al.*, 1977; Witherow, 1973; Hansen, 1980) substantiate the results of the four major surveys, although a wider variability in results was seen.

Wastewater parameters included in Table 13.1 are as follows:

(1) Biochemical oxygen demand (BOD) is a measure of the amount of oxygen required by microorganisms to assimilate available nutrients in a liquid system into microbial cells in 5 days at 20°C.
(2) Suspended solids (SS) is a measure of the total non-filterable residue that is retained on a standard glass-fibre filter after filtration.
(3) Fats, oils, and grease (FOG) are measured by extraction with hexane or freon.
(4) Total Kjeldahl nitrogen (TKN) is a measure of the total nitrogen, organic, and inorganic in a sample.

If BOD, SS or TKN is unusually high in wastewater from a meat-processing facility, other parameters are generally relatively high also (Hansen *et al.*, 1984; Pilney *et al.*, 1972). BOD is proportional to water usage; as water usage increases, the BOD concentration (mg/l) in the wastewater from the plant increases. One might expect the concentration of BOD in mg/l to be lowered with greater use of water unless the wastewater per unit of product is some kind of index of the plant's 'wastewater consciousness'. 'Wastewater consciousness' would mean greater attention is given to dry cleanup and recovery of blood, meat scraps and paunch material etc., in the plant. Plants that are wastewater conscious tend to pay attention to water conservation and thus have lower sewer and water-use bills.

MEAT-PACKING WASTE TREATMENT

Meat packing wastewater treatment schemes include most types of industrial wastewater treatment. By 1967, 99% of meat plants in the U.S.A. used some type of wastewater treatment (FWPCA, 1967). Wastewater treatment may mean anything from simple sedimentation (removal of solids by gravity) to complicated physical–biological–chemical treatment that may involve physically separating solids (sedi-

mentation, screening), biological destruction of organic matter and chemical treatment to enhance physical separation, removal of inorganics such as phosphorus, or destruction of pathogens by chlorination. A detailed discussion of wastewater treatment methods is beyond the scope of this book. There are numerous texts on the subject and treatment methods are discussed in detail in the references listed at the end of this chapter. Common methods of treating animal-processing wastewater are briefly discussed and categorized into physical treatment (Table 13.2), physical plus biological treatment (Table 13.3), land application and refeeding. Because of

Table 13.2 — Removal efficiencies of animal-processing physical wastewater treatment unit processes

Unit Operation	Removal efficiency (%)[a] SS	FOG	BOD
Screening	15–60	N/A[b]	N/A
Centrifugation	50–60	50–60	N/A
Catch basins (settling basins)	40–50	50–60	20–30
Air flotation	60	60–90	25–60

[a]Removal efficiencies reported are for ideal operating conditions.
[b]Not available.
Source: Steffen *et al.* (1973), EPA (1976).

Table 13.3 — Removal efficiencies of biological wastewater treatment systems combined with physical treatment in animal-processing plants

System	Removal efficiency (%)[a] SS	FOG	BOD
Anaerobic lagoons	86–95	95–99	85–95
Aerobic lagoon[b]	90–98	95–99	95–99
Activated sludge process and variations	97	95–97	95–99
Trickling filters	N/A	95%	86–95
Rotating biological contactor	N/A	N/A	95

[a]Removal efficiencies reported are for ideal operating conditions.
[b]In the case of mechanically aerated lagoons, some type of clarification such as a stabilization pond must be utilized after the aerated lagoon to remove SS.
Source: Wells *et al.*, (1973); EPA, (1974).
N/A: Not available.

obvious advantages for the animal processing industry, land application of animal waste is discussed in more detail.

Physical treatment systems often used in animal processing and corresponding SS, FOG, and BOD removal efficiencies are given in Table 13.2. Screens and catch basins generally require less maintenance and less energy for operation than the other two methods. Air flotation is a process where air is dissolved in wastewater under pressure. The wastewater then moves to a quiescent stage and air bubbles come out of solution carrying solids with them as they rise to the surface. Air flotation has advantages in that skimmings can be utilized as inedible grease. The highest removal efficiency for centrifugation, settling basins and air flotation requires the addition of chemical flocculates.

Biological wastewater treatment systems often follow physical treatment. These two treatment systems together are called secondary treatment. Secondary treatment systems used in the animal-processing industry are given in Table 13.3. One of the most cost effective, efficient, and popular unit processes for treatment of animal-processing effluent is the anaerobic (without air) lagoon which, when operating properly, can remove upwards of 82% of the applied BOD (in addition to that removed by physical treatment) at an average loading of 0.4 kg/day/m^3 (24.7 lb BOD/day/1000 ft^3) (Baker *et al.*, 1974). Microorganisms in an anaerobic lagoon utilize organic matter in the wastewater as food, and in the process of growth and maintenance they convert the organic matter into biogas, which is mostly methane (60–80%) (CH_4) and carbon dioxide (CO_2) (20–40%). Methane is the principle component of natural gas and can be burned to provide heat energy. Unfortunately, it is not economical to collect the methane produced in most anaerobic lagoons because of the large surface area.

Anaerobic treatment alternatives to the lagoon have been developed recently. These include the plug-flow digester for waste with a high solids concentration (Walker, 1980) and various types of fixed-film and sludge-blanket digesters (Chynoweth *et al,* 1984; Callender and Barford, 1983). The fixed-film and sludge-blanket digesters feature a longer solid retention time relative to the liquid portion of the wastewater. This allows much shorter hydraulic retention times (often at least an order of magnitude shorter) than anaerobic lagoons or conventional complete mixed digesters. The short hydraulic retention time results in smaller digesters, which facilitates methane collection and utilization. Even so, it is necessary to compare capital costs, maintenance and value of methane on a case-by-case basis to determine if a solid-retention-type anaerobic process is more economical than an anaerobic lagoon in treating animal-processing wastewater (Hansen, 1980).

The aerobic lagoon has excellent removal efficiencies and has the advantage of less odour than an anaerobic lagoon. It has a major disadvantage of requiring either artificial (mechanically aerated lagoons) or natural aeration. Naturally aerated lagoons are limited in depth to about 1.5 m (5 ft). This requires a large surface area to provide the necessary water-holding capacity. Electrical costs for the mechanically aerated lagoon generally prohibit its use for animal-processing waste unless odour emissions are of primary concern.

The activated-sludge process (Fig. 13.1) is an aerobic treatment process with recycling of microorganisms that break down the waste. Organic matter in animal-processing wastewater is biologically converted primarily into carbon dioxide, water

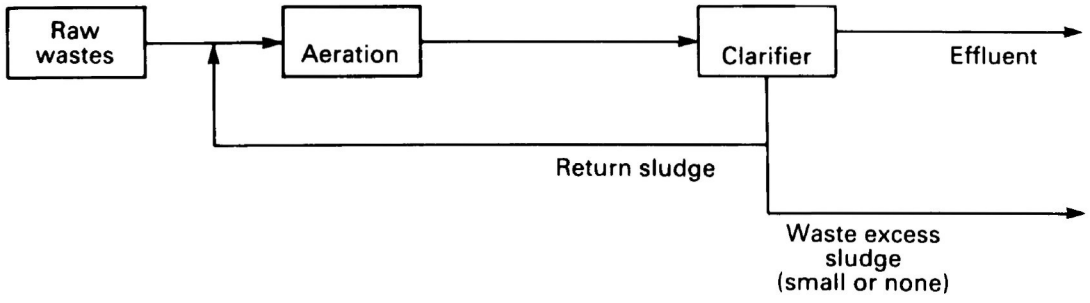


Fig. 13.1 — Activated sludge process.

and more microorganisms. These microorganisms are removed by settling and fed back into the incoming wastewater. This abundance of microorganisms quickens the rate of breakdown of organic matter several-fold relative to an aerobic lagoon. However, the activated-sludge process has disadvantages of costs for high rates of mechanical aeration, and additional management and maintenance requirements (Cheremisinoff, 1987).

A trickling filter (Fig. 13.2) is a device where wastewater is sprayed over beds of

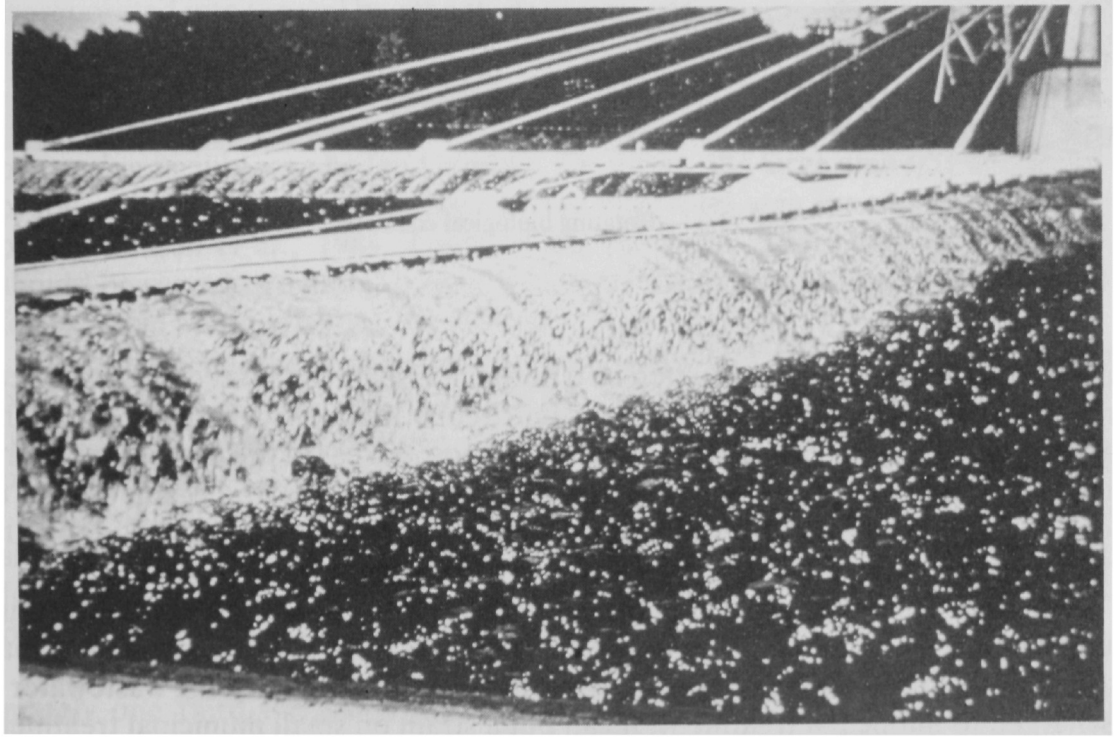


Fig. 13.2 — Trickling filter.

rock or plastic media to achieve contact between microorganisms present on the surface of the media and organic material in the wastewater. Rotary distribution arms are used to uniformly distribute the wastewater over the media. The media provides both a surface for the biological growth as well as voids for movement of air and water through the filter bed.

The rotating biological contactor (RBC) process (Fig. 13.3) consists of large

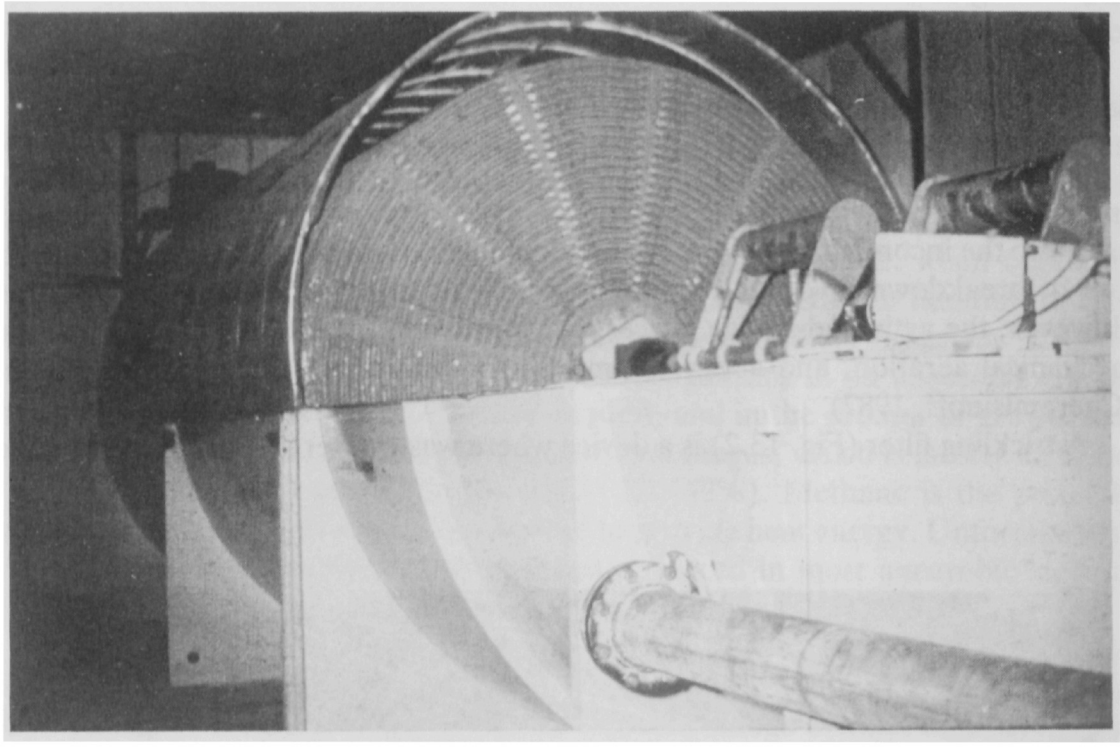


Fig. 13.3 — Rotating biological contacter.

diameter, light weight discs mounted on a horizontal shaft and placed in a semicircular tank. Wastewater is fed through the semicircular tank. Discs rotate through the wastewater, which adheres and trickles down exposed areas of the disc as they rotate out of the water. Aerobic organisms attached to the disc absorb organic matter as they rotate through the wastewater and obtain oxygen required to break down the organic matter when they are exposed above the wastewater.

Animal-processing wastewater has an extremely high strength compared with municipal sewage. Animal-processing waste averages over 1200 mg/l BOD and may exceed 2700 mg/l BOD (Loehr, 1977). If untreated animal-processing wastewater is discharged to municipal treatment, it can put a strain on small municipal treatment systems. Therefore, municipal wastewater-treatments systems either forbid discharge of these high-strength wastes or exact a surcharge to treat them. Generally municipal wastewater-treatment plants exact a surcharge on industrial wastes equal to what it costs to remove an equivalent amount of pollutants from domestic waste.

This means that an industry that discharges BOD equivalent to that from 1000 homes will pay 1000 times the fee of the homeowner. When surcharges are levied in this fashion, it is almost certain the industry will get more net benefit from pretreating waste before discharge to the municipality as compared to discharging raw waste to the municipality (Hansen *et al.*, 1984).

LAND APPLICATION OR RE-FEEDING OF ANIMAL-PROCESSING WASTE

Land application or land treatment of wastes is the surface spreading or subsurface injection (10–25 cm (4–10 in) down) of liquid or solid waste material on or into soil. This method of treatment remove a greater percentage of organic and inorganic pollutants from animal-processing waste than treatment methods discussed previously in this chapter (Stevens *et al.*, 1972). Land treatment employs mechanical, biological and chemical processes which occur naturally in or on the soil in the purification of waste water.

Organic matter in animal waste which represents high BOD is degraded by soil bacteria and becomes part of the soil matrix. Nutrients in the waste are taken up by crops or recycled into the soil (Loehr, *et al.*, 1979a).

Commercial agricultural manure spreaders and liquid-manure injection equipment are suitable for land application of animal-processing waste. Subsurface injection of offensively odoriferous material will control odours, reduce attraction of insects and conserve nitrogen. Surface-applied animal-processing waste can be incorporated into the soil by ploughing or discing soon after application. References which explain land application of wastes in more detail include Loehr *et al.*, (1979a,b) and Reed and Crites 1984.

Wastewater polluted with organics, including wastewater from an animal-processing facility, can be land applied. However, the large amounts of wastewater produced by a plant would require a very large land area for even a medium-sized plant (Hansen *et al.*, 1984, Loehr *et al.*, 1979a,b). Alternatively, waste streams should be segregated and the most heavily polluting wastes can be land applied, as for example blood at about 160 000 mg/l BOD.

The handling and disposal of manure/paunch is integral to animal processing because of the need to dispose of manure from holding pens and paunch (partially digested feed) from slaughtering. The amount of manure produced daily by livestock per animal unit (454 kg (1000 lb) live weight) is given in Table 13.4 (MWPS, 1985).

The amount and characteristics of blood and paunch manure produced from slaughtering beef are given in Table 13.5. Blood quantities per animal slaughtered for other species are given in Chapter 9. Paunch produced by ruminants other than beef can be estimated based on their size relative to beef.

The estimated expense for applying manure, paunch or blood to land is approximately one third the estimated cost for dehydration (Reddell *et al.*, 1976) in a rendering facility (see Chapter 3). Waste materials from animal processing can be beneficial for the soil. However, if these materials are mixed with water and discharged into the sewer, the wastewater has high BOD, SS and TKN, which are costly to remove using any of the methods discussed previously.

Table 13.4 — Manure production and characteristics as produced per 454 kg (1000 lb) live weight for given animal species

Animal	Manure Production				Water	VS	Nutrient Content ($kg/day \times 10^{-2}$ (lb/day))		
	(kg/day)	(lb/day)	($m^3/day \times 10^{-4}$)	(gal/day)	(%)	(kg/day(lb/day))	N	P_2O_5	K_2O
Dairy cattle	37.3	82	370	9.8	87.3	3.9 (8.6)	18.6 (.41)	7.5 (.17)	14.7 (.32)
Beef cattle	27.3	60	280	7.4	88.4	2.7 (5.9)	15.4 (.34)	11.3 (.25)	13.1 (.29)
Market pigs	29.5	65	299	7.9	90.8	2.2 (4.9)	20.4 (.45)	15.4 (.34)	16.1 (.35)
Sheep	18.1	40	174	4.7	75	3.9 (8.6)	20.4 (.45)	6.8 (.15)	17.7 (.39)
Poultry broilers	31.8	70	335	8.9	74.8	5.5 (12.1)	54.4 (1.2)	27.9 (.62)	20.4 (.45)
Horses	20.4	45	212	5.6	79.5	3.4 (7.5)	12.2 (.27)	4.8 (.11)	9.3 (.21)

Source: MWPS (1985).

Table 13.5 — Typical waste characteristics for blood and paunch for beef cattle

Parameter		Blood		Paunch manure	
		Fresh	Dehydrated	Fresh	Dehydrated
(1)	Waste quantity, (parts per thousand body weight	38	8.1	45	9.7
(2)	Moisture Content (%)[a]	80	6	80	6
(3)	Total solids, (kg/1000 kg (lbs/ 1000 lbs) body weight)	7.5	7.5	9	6
(4)	Volatile solids, (kg/100 kg (lbs/ 1000 lbs) body weight)	—	—	8.4	8.4
(5)	BOD_5[b] (mg/l)	160,000	—	50,000	—
(6)	COD[c] (mg/l)	220,000	—	180,000	—
(7)	pH	7.3	—	6.5	—
(8)	Protein (%)	20	88	2.5	12.6
(9)	Nitrogen (%)	3.3	14.2	0.4	2.0
(10)	Phosphorus (P_2O_5) (%)	0.0010	0.0047	0.3	1.46
(11)	Potassium (K_2O) (%)	0.0010	0.0046	—	—
(12)	Sodium (%)	0.029	0.135	—	—
(13)	Calcium (%)	0.001	0.047	0.13	0.59
(14)	Iron (%)	0.039	0.184	—	—
(15)	Magnesium (%)	—	—	—	—

[a]All percentages on wetweight basis. There is still some moisture in 'dehydrated' products. Dehydration is sufficient, however to reduce spoilage by microorganisms.
[b]Five day biochemical oxygen demand.
[c]Chemical oxygen demand.
Source: Reddell *et al.*, (1976).

Plant nutrient value of manure/paunch

Manure, paunch and blood (organic waste) put on land improve the tilth and add nutrients necessary for crop growth. It is difficult to predict the worth of land-applied organic waste from an improved tilth standpoint, but the value of the nutrients, which can be calculated, is significant. Organic wastes should be applied so as to

maximize use of nutrients, particularly nitrogen, phosphorus and potassium. Phosphorus and potassium usually are bound in the soil, whereas nitrogen, if applied in excess of crop requirements, will leach out of the soil and contaminate receiving waters. Therefore, available nitrogen should not exceed the nitrogen requirements of the crop to be grown on the soil. Nitrogen requirements and yield goals for selected crops are given in Tables 13.6 and 13.7.

Table 13.6 — Amount of nitrogen recommended annually for corn based on previous crops

	Yield Goals	
Corn, grain	13.9 m^3/ha (160 bushels/acre)	17.4 m^3/ha (200 bushels/acre)
Corn, silage	48.2 tonne/ha	60.5 tonne/ha
Previous crop	Annual N application recommended (kg/ha (lb/acre))	
Forage legume	112 (100)	168 (150)
Grass crop	168 (150)	196 (175)
Soybeans	191 (170)	280 (250)
Continuous corn and other crops	224 (200)	336 (300)

Source: White and Logan, (1981).

Table 13.7 — Amount of nitrogen recommended annually for selected crops

Crop	Yield goal	Annual N application recommended. (kg/ha) (lb/acre))
Wheat	4.4 m^3/ha (50 bushels/acre)	17 (15) (autumn)[a]
		45 (40) (spring)
Oats	8.7 m^3/ha (100 bushels/acre)	45 (40) (spring)
Forage legume	11.2 tonne/ha (5 tons/acre)	73 (65) (split)
	14.6 tonne/ha (6.5 tons/acre)	95 (85) (split)
Grass crop	11.2 tonne/ha (5 tons/acre)	95 (85) (split)
	14.6 tonne/ha (6.5 tons/acre)	140 (125) (split)
Soybeans	A legume can fix adequate atmospheric nitrogen for 5 m3/ha (60 bushels/acre) to 6 m^3/ha (70 bushels/acre).	

[a]Time of year waste is applied.
Source: White and Logan (1981).

Nitrogen in organic waste including animal processing waste is of two forms, organic and ammonia. The nitrogen in the ammonia form is available when spread. However, if the organic waste is spread onto the surface, sizable amounts of

ammonia N may be lost to the atmosphere by volatilization. Only one-third to one-half of organic N is available to plants in the year it is spread (White and Logan, 1981; MWPS, 1985). Organic N released (mineralized breakdown of organic N to available ammonia N) during the second, third and fourth cropping years after initial application is usually about 50%, 25% and 12.5% respectively of that mineralized during the first cropping season (MWPS, 1985).

To determine how much nitrogen will be available to crops from land application of animal-processing waste, it is necessary to have the waste analysed (this can be done at most state universities in the USA or at a commercial laboratory). Records should be kept of each year's application. The total nitrogen available to the crops will be the cumulative amounts of N mineralized from previous year's applications of organic N plus the present year's application of ammonia N. For purposes of estimating, one might conservatively estimate the nitrogen in paunch and manure to be about 50% organic and 50% ammonia N. The nitrogen in blood is nearly all organic but is easily broken down and made available to plants. The exact rate of mineralization in animal-processing waste depends on a number of factors and it is recommended that soil be tested each year to determine actual nutrient levels. State universities or many commercial laboratories will test soil. With soil and waste analysis, animal-processing waste can be precisely applied in amounts that will meet crop needs. Laboratories that test soil and wastes often recommend application rates based on the test results.

Animal-processing waste is a good source of phosphorus and potassium (P&K). Nearly all of the P&K in animal-processing wastes is available for plant use the year of application. If animal-processing waste has been applied to land regularly over the years, soil test levels for P&K should be in the adequate to high range. Applying large amounts of animal waste to these soils is inefficient because P&K will begin to exceed crop requirements and can cause trace nutrient deficiencies in plants. For example, excess levels of available P may lead to zinc deficiency in plants (White and Logan, 1981). Animal waste application rates should be designed to match the nutrients removed by the crop. Table 13.8 lists approximate amounts of nutrients

Table 13.8 — Approximate amounts of plant nutrients removed from soil by selected crops

Crop and yield goal	N (kg/ha (lb/acre)	P_2O_5 (kg/ha (lb/acre)	K_2O (kg/ha (lb/acre)
Alfalfa (lucerne) 13.4 tonne/ha (6 tons/acre)	381 (340)	90 (80)	404 (360)
Corn: 13.9 m^3/ha (160 bushel/acre)	163 (145)	67 (60)	50 (45)
Corn: 17.4m^3/ha (200 bushel/acre)	202 (180)	84 (75)	62 (55)
Corn silage: 60.5 Tonne/ha (27 tons/acre)	275 (245)	95 (85)	275 (245)
Soybeans: 4.4m^3/ha (50 bushel/acre)	213 (190)	45 (40)	78 (70)
Soybeans: 5.7m^3/ha (65 bushel/acre)	275 (245)	56 (50)	101 (90)2
Wheat: 0.9m^3/ha (55 bushel/acre)	78 (70)	39 (35)	22 (20)

Source: White and Logan (1981)

removed from the soil by several crops. Again, animal waste and the land to which it is being applied should be tested on a regular basis to ensure that the P & K in the waste is assimilated. If soil is high in P & K, then additional nitrogen in a commercial form should be applied or legumes should be grown that supply their own nitrogen.

An example problem for land-application of animal-processing waste is given in the appendix to this chapter.

RE-FEEDING

Manure, and more particularly paunch manure, may be more valuable as a feed ingredient than as a source of plant nutrients. These wastes can be mixed with feed and re-fed to meat-producing animals. Ruminants have microorganisms in the rumen that can utilize fibre and non-protein nitrogenous compounds to a greater extent than non-ruminants, so there is additional benefit from feeding non-ruminant manure and paunch to ruminants. Neither the quantity of animal products nor their palatability is affected when waste is fed at nutritionally acceptable levels (Day and Sweeten, 1979).

On the other hand, manure/paunch may contain pathogens, parasites, residues of drugs, excess levels of metal ion and contaminants of natural or industrial origin, such as glass, metal or wood. The re-feeding of animal waste could be hazardous to animals unless contaminants are removed or kept at acceptable levels. Some form of processing is necessary to obtain pathogen kill, reduce odours, preserve nutrients and enhance palatability. Some successful methods include drying, chemical treatment or biological treatment.

Biological treatment of the animal waste by ensiling with corn or other normal feedstuff has been shown to be inexpensive and effective in increasing palatability and nutritive value. Prepared in this manner, animal waste can replace up to 50% of the normal feedstuffs required by livestock. (MWPS, 1985)

ANIMAL-PROCESSING POLLUTION REDUCTION

Pollution reduction within animal-processing plants involves good housekeeping and common sense. Avoiding spills, avoiding disposal of scraps or blood into floor drains and utilizing by-products in as high a quality product as possible is good housekeeping (see Chapter 3). Concepts of pollution reduction by good housekeeping and careful husbandry of waste and energy resources should be taught to employees and emphasized on a regular basis. Plant management should also continually investigate changes in processing techniques that could decrease pollution and increase profits. Implementation of desirable changes is not always simple. Capital costs and/or production delays may be unacceptable, therefore, it is important to first conduct a plant survey for the purpose of evaluating energy usage and pollution-reduction process changes based on potential net benefit.

In-plant reduction survey strategy

The first stage of an in-plant reduction study is a walk-through survey to identify points of water use, gross spillage and collections of blood or scraps on the floor. This

visual survey will identify gross problems and will target processes for an in-depth evaluation, including more-complete data acquisitions.

The second stage is to get information for decision making as inexpensively and quickly as possible and without a large-scale measurement program. Since water savings alone can be significant, flow measurements should be made for those processes that have been estimated (in the previous stage) to require large amounts of water and for which there might be an alternative. Composite wastewater samples should be taken and analysed to determine wastewater characteristics such as oxygen demand, solids — both suspended and dissolved — and nitrogen. Energy consumption should be measured when applicable. The monitoring program may be organized as outlined in Fig. 13.4. In making the waste survey itself, one should normally:

(1) Develop a flow sheet for the process.
(2) Determine where waste samples are to be taken.
   (a) Review building plans and determine the number and location of sewer outfalls from the process.
   (b) Determine types of energy (electricity, steam, etc.) used in the process and location of steam lines, wires, etc.
   (c) Determine solid waste outflows from the process.

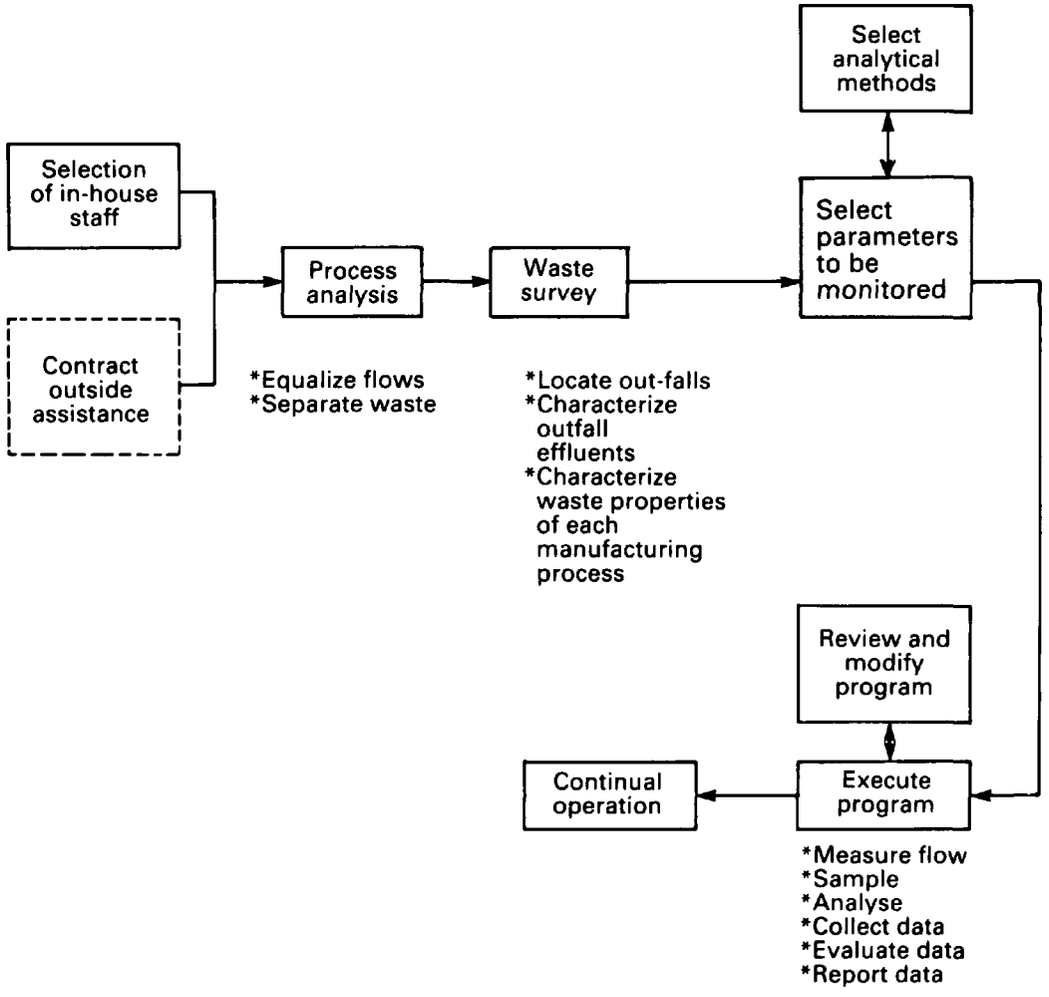


Fig. 13.4 — Steps involved in establishing a monitoring program. Source: Berthouex *et al.* (1977).

(3) Determine sampling locations.
(4) Determine how energy data, flow and waste samples are to be collected.
(5) Determine the duration of the sampling period.
(6) Determine the analyses to be performed.
(7) Check raw and finished product receipts.
(8) Review subunit processes within the process and monitor if necessary.
(9) Review maintenance and spillage reports.
(10) Determine calculations needed to reduce collected data for evaluation of the process.

The third stage of in-plant reduction study is to generate a list of possible solutions for each problem site, such as broom and shovel pick-up, installation of catch troughs, curbing an area to divert water, installation of an automatic shut-off, use of an alternative process, etc. Engineers, the plant manager, maintenance staff and workers involved with the process should all be involved in finding solutions. Each solution should include an optimistic and pessimistic economic outcome. In order to make these estimates, the solution-generating team must know the cost of water, energy, labour, sewage treatment surcharges, the probable impact of industrial cost-sharing in the community, likely changes in the required level of wastewater treatment and the selling price of renderings, grease or other marketable materials that may be affected by changes in the process.

The solution-generating team should consider several alternatives, including not changing the process or recommending that more data be collected before making a decision. Some solutions may be conditional; as for example contingent on disproportionate cost increases for labour and electricity. Otherwise, the survey team should prioritize possible solutions, and recommend implementation of the best solutions.

In-plant modifications to reduce pollution

First Case Study

An example of a successful in-plant reduction project is that performed by Berthouex *et al.* (1977) in hog-packing facilities. Although the project data was limited to hog processing, the problems and solutions reported here have application to all types of animal processing. Dollar values are given that will change with time; however, the given ratios, adjusted for price change and commodity or utility savings, will still be appropriate.

Process change in the bleed area

Problem: After the last animal was killed for the day, six sprays along and above the bleed trough were started to wash some of the blood from the troughs to the blood recovery system. The first sluice of water went to the blood recovery system; after this short initial sluice, drainage was diverted from the blood recovery system to a floor drain. The first sluicing removed only about 50–60% of the blood in the trough

and this blood, obviously, was diluted as it entered the blood recovery system. Another inefficiency associated with this practice was that the remaining 50% of the blood was washed into a floor drain during the clean-up shift.

Solution: A squeegee with an offset handle was made to remove blood from the blood trough into the blood recovery system without using the initial sluice of water. This dry cleaning procedure increased the amount of blood recovered from 50% of that on the trough as clean-up began to 80–90% of the blood that was on the trough at the start of clean-up. This is an increase of 11.3 kg (25 lb) of blood and represents 2.3 kg (5 lb) of BOD removed from the wastewater system. Not only is more blood recovered by this method, but the cost of recovering the blood was reduced because the water added to clean-up did not have to be handled and heated in the blood recovery process. The only blood from the bleeding trough, then, that did not go to blood recovery was blood which was inaccessible because it was beneath surfaces or in pipes where the squeegee could not reach. Additional labour required was considered insignificant.

Process change for the rail polisher

Problem: Water use in the rail polisher was too high, principally because clean-up personnel left the sprays on during clean-up shift. This water served no useful purpose.

Solution: One solution was better training and supervision of clean-up personnel. This was not always easy to accomplish, so a mechanical solution was developed and tested. An automatic switch was installed that turns off the water when the last animal has gone through the rail polisher. A steel push bar is depressed by the hog trolley to activate a solenoid valve on the water supply to the rail polisher. If there are not any hogs going through, the water supply is automatically shut off. There is bypass piping and valving around the solenoid for use in case of malfunction. To discourage improper use of this bypass, the hand-operated valve is inaccessible without a ladder. Different switching mechanisms, perhaps light rays and photo-receptor tubes, could be used to shut off the water between the passage of individual hogs. The savings from this sophisticated system would be at most half of the the total water use during the production shift, or 48.5 kl/day (12 800 gallons/day). The more reasonable target is to eliminate wastage during the clean-up shift which is 6.2 kl (1,640 gallons) every hour these sprays are left on. The cost of the automated shut off was $255.00. The estimated annual saving in water use was 6.1 Ml (1 600 000 gallons) (6 400 gallons/day×250 day/year) equal to $624.00.

Process change for carcass shower

Problem: The problem was excessive water use. The final carcass shower required 3.78 l/s (60 gallons per minute).

Solution: Different kinds and configurations of nozzles were tried to reduce the volume of water required to clean the carcasses. In a Madison, Wisconsin, plant, a series of six Veejet nozzles (Spraying Systems Co.) was installed to spray the top of the carcass to sluice off loosened soil. These nozzles removed dirt satisfactorily from the carcass and reduced the water use from 3.78 to 2.7 l/s (60 to 43 gpm) or a 33 kl/day (8753 gallons/day) reduction in water usage. This was also equivalent to

50.8 l/1000kg (6.1 gallon reduction/1000 lb) of live weight kill. Table 13.9 lists savings in terms of flow reduction and costs respectively.

Change in carcass work-up area

The carcass work-up area is defined as that part of the kill floor after the final carcass shower where the carcass is being trimmed, cut and split. In this section the focus was on controlling the amount of water, meat and fat scraps, and blood that fell onto the floor under and around the kill chain. Pollution was eliminated by properly handling these scraps and drippings.

Problem: Tissue scraps removed from the carcass after the carcass shower were dropped onto the floor. Despite periodic dry pick-up, many of these scraps were washed into the drain by water originating in the carcass shower.

Solution: A combination bridge and screen was built to fit across the drain and gutter to keep tissue scraps out of the drain. About 5.4 kg (12 lb) of this scrap formerly entered the drain. The amount of grease, BOD, etc. removed was not known, but there is no doubt that this simple change has reduced the pollution load.

Problem: Trimmings, blood clots, and meat and bone dust from carcass splitting littered the carcass work-up area. Mid-shift and final clean-up personnel often found it more convenient to flush this material into a drain rather than use dry clean-up methods. This caused a large periodic pollution load and lost material for inedible rendering. Dry clean-up with a broom and shovel, the normal procedure, was an effective procedure. An industrial vacuum cleaner readily picked up blood, floor scraps, sawdust, and even whole kidneys and left the floor to dry, but it was cumbersome and slow. Some congested areas were not accessible. A man with a broom and shovel could do almost as well in less time and with less interference to kill-line operations. The vacuum system could be used to good advantage in some places, particularly if installed as a central system, thereby eliminating the cart, electrical cords, and movable tank.

Problem: When the hog brisket was split open and when viscera was removed, large clots of blood fell into the gutter beneath the kill rail. During mid-shift and final clean-up these were often pushed down the chute leading to the hasher–washer rather than being picked up for rendering. Sluicing to the hasher-washer breaks up the clots and leaches substantial amounts of soluble material.

Solution: The solution was dry clean-up. Training and supervision of personnel is vital. Vacuum cleaning would be effective in some places.

Changes in viscera handling

Problem: There was a continual loading of blood and other materials that were washed off the eviscerating treadmill by water-spray. These sprays used a total of 57 l/min (15 gallons/min), part of which was 82°C (180°F) water to sanitize the treadmill and part of which was cold water-spray to loosen blood and other matter. The problem was to reduce the amount of water used for washing.

Solution: Experiments showed that cleaning with only 19 l/min (5 gallons/min) of water was sufficient. The reduction in water use was accomplished by installing new nozzles in the spray system. The change saved 17.7 kl (4670 gallons) of water/day on

Table 13.9 — Annual savings due to carcass shower reductions

Item	Amount
Flow savings, 1 year:	
33 kl/day (8753 gallons/day) = 8.3 Ml/year	
(2 188 250 gallons/year) @ $0.39/1000 gallons	$853/year
Present value of savings (5 years @ 10%)[a]	$3,233
Total cost of installing change	$184
Estimated net present value of savings	$3,049

[a]This is the amount that must be invested at 10% interest to secure annual payments equal to the savings ($853 in this case) each year for five years.
Source: Berthouex *et al.* (1977).

the treadmill alone, which resulted in an annual savings of $455.00†. The cost of making the change was $63.00.

Problem: Excessive amounts of water were being used on the viscera pans and the visceration treadmill during clean-up. The clean-up men would leave the viscera pan and treadmill sprays on during most of the clean-up. After the first 30 minutes, this accomplished no useful purpose.

Solution: Solenoid valves were installed on the three water lines that supply the viscera pan sprays and treadmill sprays. These valves are controlled by a locked timer box. During production the timer is set on manual operation and the solenoid valves remain open. At the end of production the timer is set on automatic and the control cabinet is locked. To use the sprays the clean-up man must push a button on the control cabinet to activate the timer and open the water supply valve. The timer automatically closes the solenoid valve after 15 minutes. The sprays can be restarted by pushing the button again if more water is needed, but they cannot be left running by inaction or carelessness. This automated lockout would not be required if clean-up workers were properly motivated toward good conservation practices and were well supervised. In many plants automation will be the practice that is certain and effective. Table 13.10 documents the savings accomplished by using this automated valve during clean-up shift.

Change in the hasher–washer

Problem: The hasher-washer drain was the largest contributor of pollution load from the kill floor. Intestines and great quantities of other solid materials were sluiced into the hasher–washer from various parts of the kill floor. Knives in the hasher–washer slashed the intestines and this enabled the sluice water to flush out the intestinal contents. The objective was to have fat and meat solids go to inedible rendering and to have wastewater go to the wastewater-treatment plant. The separation of solids and the liquid was very inefficient. Large quantities of solids escaped with the water through the large slots in the hasher–washer drums. This represents an extremely

† 10 gpm (7.79 hour/day) (60 min/hour) (250 day/year) ($0.39/1000 gallons) = $455/year.

Table 13.10 — Annual savings due to use of lockout switch for cleanup of evisceration Treadmill[a]

Item	Amount
Annual savings:	
7 456,250 gallons @ $0.39/1000 gallons	$2907
Present value of savings:	
5 years @ 10%	11 019
Installation cost	$1285
Net present value of savings	$9734

[a]No change in BOD or SS; flow reduction = 113 kl/shift (29 825 gallons/shift)=28.2 Ml/year (7 456 250 gallons/year).
Source: Berthouex *et al.*, (1977).

high load in terms of BOD solids, grease, and other pollutants that were disposed of at the municipal wastewater treatment plant.

Solution: The chopping blades were removed from the hasher–washer so the unit functioned only as a dewatering device. The large and small intestines and their contents remained intact and were sent to inedible rendering. This increased the quantity of meat scrap and material for rendering by an average of 3856 kg/day (8500 lb/day). The value for rendered meat scrap was 3856 kg/day ($5.75/100 lb); thus $0.13 kg (8500 lb/day) is worth $488.75. The additional income was not the total savings associated with the change because allowance must also be made for savings in wastewater treatment. Analysis of meat meal produced during the test period did not indicate reduction in the quality, although the crude fibre content of the meal did increase from 1.5% to 1.7%.

The solids from the hasher–washer were rendered to produce grease and meat meal. During the test with the hasher–washer blades removed, there were several customer complaints about the quality of the choice white grease. Some of this grease had to be downgraded to A-white with the resultant loss in the selling price of $0.75/100 weight. (Choice white grease was $14.75/100 weight, and A-white grease, which is lower quality, was $14.00/100 weight). During a four-year period at the time of the study, the plant produced an average of 5 188 000 lb (2353 Mg) of choice white grease/year. If this total production were downgraded to A-white, there was a loss in income of $25 940/year. This was offset by the increase in meat scraps going to rendering, estimated as $488.75/day, which over 250 working days/year approximates $122 000. The extra cost of drying the additional meat scraps, the savings in power and maintenance in not running the hasher, and savings in wastewater treatment were not included. Removing the hasher–washer blades gave a substantial reduction in BOD, suspended solids, and other pollutants going to the wastewater treatment facility. Tables 13.11 and 13.12 contain detailed pollution and cost data.

Second case study

An in-plant pollution reduction study by Hansen *et al.* (1983) revealed that better in-plant water management results in significant energy saving, reduced wastewater

Table 13.11 — Reduction in production shift pollution load due to removal of hasher washer blades

Item	Pollution load (parts per thousand (by weight) 1 wk			
	Before change	After change	Net reduction parts per thousand (by weight) lwk	Total for plant (kg/day (lb/day))
Flow	No change	No change	—	—
BOD	2.70	0.6498	2.050	1337 (2948)
SS	2.35	0.324	2.020	1318 (2906)
Grease	2.83	0.255	2.625	1712 (3775)
TKN	.23	0.134	0.096	63 (138)
COD	6.80	1.581	5.219	3404 (7505)

Source: Berthouex *et al.*, (1977).

Table 13.12 — Annual savings due to removing the hasher blades (based on 250 work days/year and costs of \$1.48/m^3, \$0.39/1000 gallons, \$0.07/kg (\$0.0319/lb BOD), and \$0.06/kg (\$0.0264/lb) SS

Item	Amount
Flow savings	None
BOD savings:	
2948 lb/shift = 737 250 lb/year (334 110 kg/year)	\$23 518/year
SS savings:	
2906 lb/shift = 726 500 lb/year (329 540 kg/year)	\$19 179/year
Total annual savings	\$42,697
Annual added value due to increased meat scrap:	
3860 kg/day (8500 lb/day) = 963 894 kg/year (2 125 000 lb/year) @ \$0.13/kg (\$5.75 per cwt)	\$122 187/year
Annual loss due to downgrading grease quality	\$25 940
Annual net savings	\$138 944
Present value of savings	
5 years @ 10%	\$526 681
Cost of modification	\$275
Net present value of savings	\$526 406

Source: Berthouex *et al.*, (1977).

treatment and potable water conservation. In a study of 16 meat- and poultry-processing plants major water and energy conservation opportunities common to most of the plants were identified including the following examples. Costs and savings given in dollars will change with time, but the payback periods and ratios of costs to savings will inicate benefit to processors.

Reduce hot water usage by lowering hot water temperature and using nozzles with automatic shutoffs on cleaning hoses

A number of the plants visited were using flexible hoses to wash process equipment, floors and walls. Many times these hoses did not have spray nozzles or automatic shutoffs and the temperature of the water used for clean-up was not closely monitored. At one plant the clean up water was so hot that it flashed into steam as it came out of the hose. For general cleaning purposes, water does not need to be any hotter than 49°C (120°F). Part A of this section discusses conservation by lowering water temperatures. Part B looks at the use of automatic shutoffs and nozzles on hoses, product water sprays, and hand washers.

A. Lowering water temperatures

Annual savings for lowering water temperature from 71°C (160°F) to various temperatures are presented in Table 13.13. The ease of lowering water temperature

Table 13.13 — Annual energy and cost savings per hose from lowering hot water temperature from 71°C (160°F)[a]

New temperature setting °C(°F)	Energy savings (therms/year)[b]	Cost savings using natural gas at \$4.95 per 1000 ft^3 (28.3 m^3) \$\$/Year
68.3 (155)	826	580
65.6 (150)	1651	1170
62.8 (145)	2477	1750
60 (140)	3303	2340
57.2 (135)	4128	2920
54.4 (130)	4954	3500
51.9 (125)	5780	4090
48.9 (120)	6605	4670
46.1 (115)	7431	5260
43.3 (110)	8257	5839
32.2 (90)	11560	8174
26.7 (80)	13211	9342

[a]Assume: (1) use of hose 6 hours/day, 250 days/year.
(2) Flow rate/(hose) is 831 l/min (22 gallons/min).
(3) Incoming water temperature average is 16°C (60°F).
(4) Gas is used to heat water and system is 70% efficient.

[b]Therm = 1×105 Btu (0.11 GJ).

at a food processing plant may depend on the type of hot water system found at a plant. If hot water is provided by a standard domestic-type water heater, the temperature can easily be lowered by resetting the dial. Hot water is most often provided by blending steam with unheated plant water at the point of use. The water temperature is controlled by manually adjusting the steam and water blending valves. Steam pressure and/or water pressure may vary throughout the day, which will cause the water temperature to vary. Since a minimum temperature of wash or rinse water is often required, an operator may open steam valves enough so that hot water never goes below a certain temperature. This causes unnecessarily high water temperature when steam pressure is up or water pressure is down. Sometimes an untrained operator will set water temperature high and needlessly waste energy. Manually set water temperatures should be carefully monitored. A solution that is probably better than frequent monitoring is to install thermostatically controlled steam and water blending valves that automatically control water temperature.

The payback on these valves, which cost \$450–\$700, will depend upon present water temperature settings and variation of temperature above the settings. An added advantage of automatic control valves is that automatic shutoffs (discussed in Part B, below) can usually be used on hoses attached to those valves. Calculations are given for a plant where water temperature for one cleaning hose was observed to be 100°C (212°F).

Energy savings calculations for lowering temperature of clean-up water at one station by installing an automatic temperature-control steam/water-blending valve:

Assume:

(1) Present water temperature is 100°C (212°F).
(2) Flow rate is 83.3 l/min (22 gallons/min).
(3) Required clean-up water temperature is 60°C (140°F).
(4) Gas is used in steam boiler @ \$0.495/therm (1 therm=100 000 Btu (0.11 GJ)).
(5) Steam/water blending is used to provide hot water.
(6) System is 70% efficient
(7) Hose is used 2 hours./day, 250 days/year.

$$\frac{(22\ \text{gallons/min})\ (60\ \text{min/hour})\ (2\ \text{hours/day})\ (250\ \text{days/year})}{(8.34\ \text{lb/gallon})\ (1\ \text{Btu/lb°F}) \times (212°\text{F} - 140°\text{F})\ (1/0.7)} \tag{13.1}$$

$$= \frac{5.66 \times 10^8}{\text{year}}\ \text{Btu's} = \frac{0.54\ \text{TJ}}{\text{year}}$$

Value of energy saved:

$$\frac{5.66 \times 10^8}{\text{year}}\ \text{Btu's}\ \frac{\$0.495}{106\ \text{Btu}} = \$2802/\text{year} \tag{13.2}$$

Costs:

Base cost is $700
Amortized cost (8%/year for 10 years) = 700/6.71 = $104.32
No operating or maintenance cost
Annual savings
2802 – 104.32 = $2697.68
Simple payback

$$\frac{700 \times 12}{2802} = 3 \text{ months} \tag{13.3}$$

B. Automatic shutoffs and nozzles on cleaning hoses, product water sprays, and hand washers.

Potential annual savings for shutting off hot water flows, when they are not being utilized, can be determined from Figs 13.5 and 13.6. Many plants have been able to

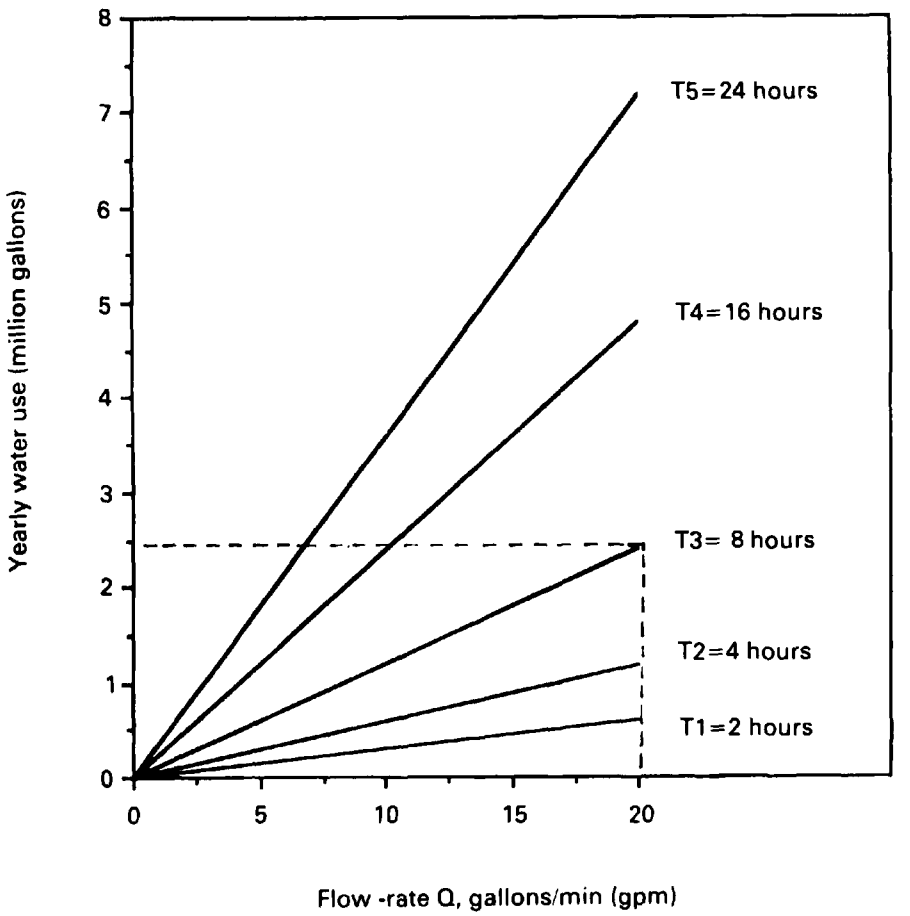


Fig. 13.5 — Yearly water use as a function of flow rate (Q) and daily usage (T). 1 million gallons is equal to 3.78 Ml, 1 gpm=3.78 l/min. Source: Hansen *et al.* (1983).

reduce water usage by installing automatic shutoffs and/or nozzles on cleaning hoses, product water-sprays, and hand washes. Electric or air-operated valves can be installed that shut off all product water-sprays whenever the processing line stops.

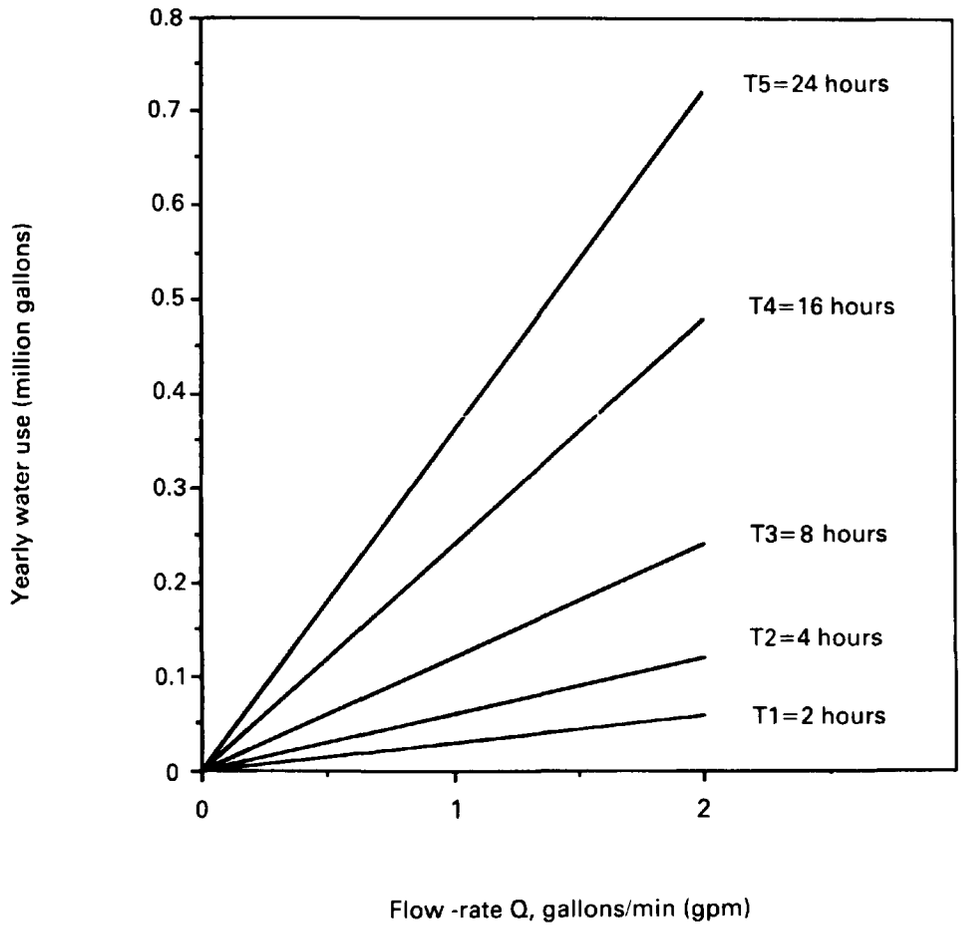


Fig. 13.6 — Yearly water use as a function of flow rate (Q) and daily usage (T). 1 million gallons is equal to 3.78 Ml, 1 gpm=3.78 l/min. Source: Hansen *et al.* (1983).

Automatic trigger-control shutoffs similar to those used on garden hoses can easily be installed on industrial hoses. They can be added to cleaning hoses with no other modifications if a water heater is used to provide hot water. If a steam/water-blending valve is used to provide hot water it is necessary to install check valves to insure steam or water does not back up into the wrong line. Automatic shutoff valves are often sold with nozzles attached. Nozzles increase water impact while decreasing flow. If nozzles are installed without automatic shutoffs the equipment cost is less than \$10.00/nozzle. An automatic trigger-controlled shutoff with a nozzle will cost approximately \$90.00. Calculations are shown for installing a hose-end automatic shutoff valve and nozzle on a clean-up hose. It was assumed that the hose ran 4 hours/day before installing the automatic shutoff and 2 hours/day after installation. The temperature of the water was 71°C (160°F).

Example 1 *Energy savings calculations for one station by installing an auto shut-off valve and nozzle on a clean-up hose*:

Base cost is \$90.00
Annual amortization (8% for 10 years) is 90/6.71=\$13.41

Assume:

(1) Hose flow is 76 l/min (20 gpm) before installing nozzle and 57 l/min (15 gpm) after installation.
(2) Water temperature is 71°C (160°F).
(3) Hose flow is 8 hours/day before installation of auto shut-off and 4 hours/day after installation.
(4) Water costs $0.80 3785 l (1000 gallon).
(5) Efficiency rate for treating water is 70%.

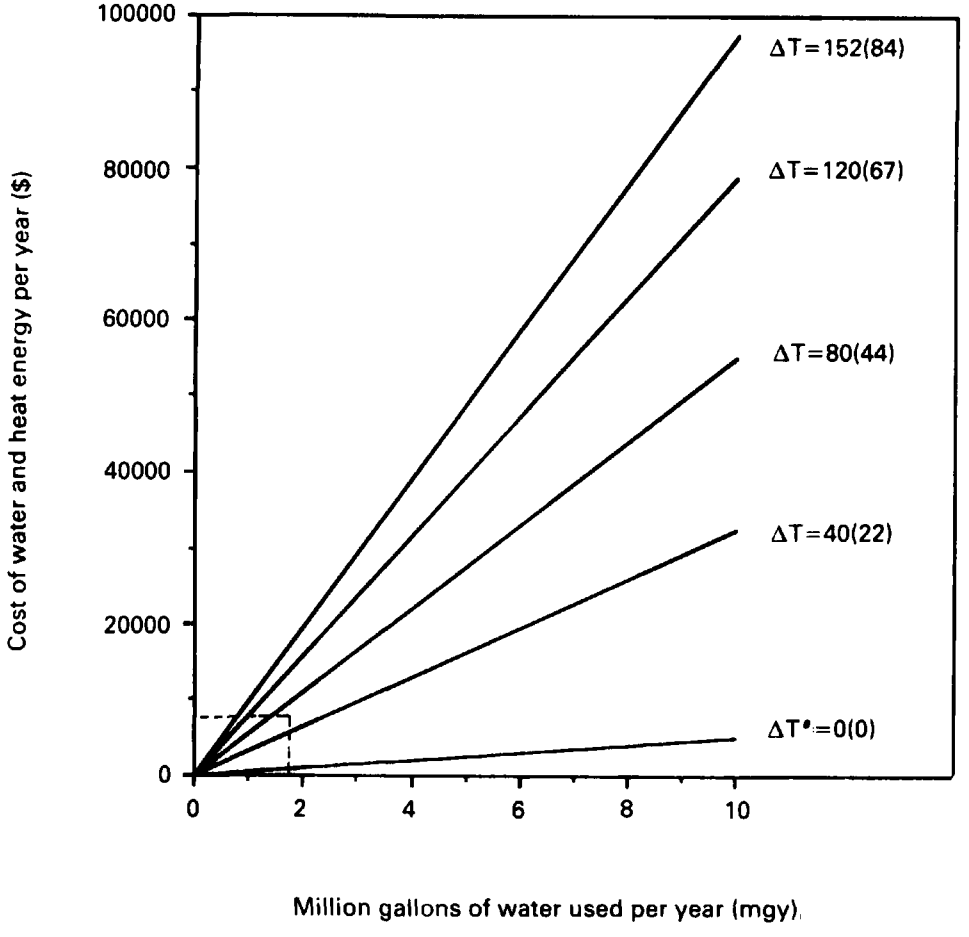


Fig. 13.7 — Cost of heat energy and water as a function of water use and temperature (T). mgy=3.8 Ml/year; *ΔT is change in temperature in °C (°F) from water coming into the plant to temperature of use. At ΔT=0, water is assumed to be 16°C (60°F). Source: Hansen *et al.* (1983).

*Water savings (from Figs 13.5–13.7).

From Fig. 13.5 yearly water use is seen to be 9.5 Ml before and 4.9 Ml after the installation of the value.

$$9.5-4.9 = 4.6 \text{ Ml/year} .$$

The value of this water (Fig. 13.7) is about $5000.00.

Annual savings is 5000−13.41 = $4986.59 (13.4)

Payback period is immediate

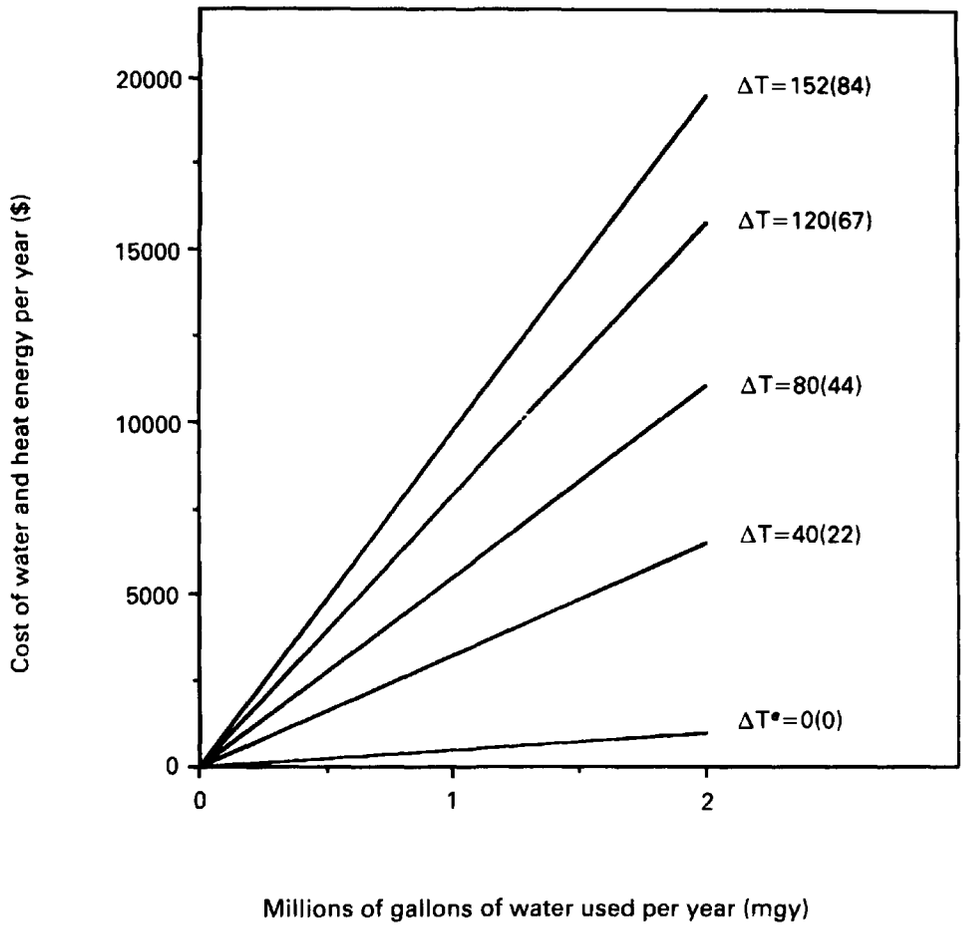


Fig. 13.8 — Cost of heat energy and water as a function of water use and temperature (T). 1 million gallons is equal to 3.78 Ml; *ΔT is change in temperature in °C (°F) from water coming into the plant to temperature of use. At ΔT=0, water is assumed to be 16°C (60°F). Source: Hansen *et al.* (1983).

Annual energy savings:
Value of water
$(0.6\times10^6$ gallons) (0.80/1000 gallons)=$480.00
Amount of energy
(3500/year−480year) ($1.0\text{x}10^5$ Btu/0.495) (1.0/0.7)
=871 million Btu/year = 0.919 TJ/year (13.5)

Use high pressure low volume sprays for clean-up

High-pressure low-volume (HPLV) water-sprays for clean-up of food processing plants will often save water and energy. HPLV involves pumping cleaning water or a water–air mixture to 4.1–8.3 MPa (600–1200 psi). Chemical cleaning aids are mixed with the high-pressure water and the mixture is sprayed against the surfaces to be cleaned. These systems are especially effective for cleaning complex processing equipment. Cleaning systems are also available that use moderate pressures, 1.4–4.1 MPa (200–600 psi). The goal should be to use as little water as necessary to do the job. The value of the water saved is usually not as much as the value of the energy saved by not having to heat as much water.

Example 2 Energy saving with HPLV clean up:
Energy requirement calculations for a hot-water hose discharging 83 l/min (22 gpm) 0.41 MPa (60 psi), 71°C (160°F) for 4 hours daily:
Assume:

(1) Incoming water is 16°C (60°F)
(2) No additional pumping required to bring pressure to 0.41 MPa (60 psi). Energy to heat water: (22 gal/min.) (8.34 lb/gal) (60 min/hr) (Btu/lb°F.) (160−60°F.)=1.1×10^6 Btu/hour=1.16 GJ/year

Value of heat in water:

(1) Natural gas boiler heats water.
(2) Boiler is 80% efficient.
(3) 1 therm of gas is 1.0×10^5 Btu (0.11 GJ).
(4) 1 therm of gas cost \$0.495.

$$\frac{(1.1\times10^6 \text{ Btu/hour}}{1.0\times10^5 \text{ Btu/therm}} (0.495/\text{therm})\ (1/0.8) = \$6.81/\text{hour} \qquad (13.6)$$

(5) Hose flows 4 hours daily

$$\$6.81/\text{hour}\ (4 \text{ hours}) = \$27.25/\text{day} \qquad (13.7)$$

Energy requirement calculations for a high pressure low volume clean up system discharging 30.3 l/min (8 gpm), 4.1 M Pa (600 psi), 71°C (160°F) 4 hours daily
Assume:

(1) Incoming water temperature is 16°C (60°F).
(2) Pump efficiency is 50%.
(3) Electricity costs \$0.05/kW h

Value of heat in water:

Use 30.3 l/min (8 gpm) instead of 83.3 l/min (22 gpm) for low-volume effectiveness
(Use ratio): (8/22) \$27.25/day = \$9.91/day (13.8)

Pumping costs:

$$(8 \text{ gpm})\ (600 \text{ psi})\ \frac{(1 \text{ hp min})}{33000 \text{ ft lb}}\ \frac{(1 \text{ ft}^3)}{7.48 \text{ gallons}}\ \frac{(144 \text{ in}^2)}{1 \text{ ft}^2}\ \frac{(1)}{0.5} = 5.6 \text{ hp} = 4.2 \text{ kW} \qquad (13.9)$$

$$(5.6 \text{ HP}) \frac{(0.746 \text{ kW})}{\text{hp}} (4 \text{ hours/day}) (\$0.05/\text{kW h}) = \$0.84/\text{day} \quad (13.10)$$

Total costs:

$$\$9.91 + 0.84 = \$10.75/\text{day} \quad (13.11)$$

Energy saving calculations per station (hose)
Pumping energy
1 horsepower hour is 2545 Btu

$$(5.6 \text{ hp}) (4 \text{ hour/day}) (2545 \text{ Btu/hp hr}) = 57\,000 \text{ Btu/day} \quad (13.12)$$

Energy in water:

$$(1.1 \times 10^6 \text{ Btu/hour}) (8/11) (4 \text{ hr/day}) = 1.6 \times 10^6 \text{ Btu/day} = 1.7 \text{ GJ/day} \quad (13.13)$$

Total energy for hose at plant pressure

$$(1.1 \times 10^6 \text{ Btu/hour}) (4 \text{ hour/day}) = 4.4 \times 10^6 \text{ Btu/day} = 4.6 \text{ GJ/day} \quad (13.14)$$

Value of energy saved:

$$(4.4 \times 10^6 - 1.657 \times 10^6) = 2.743 \times 10^6 \text{ Btu/day} = 2.9 \text{ GJ/day} \quad (13.15)$$
$$\$27.25 - \$10.75 = \$16.50/\text{day} = \$4125/\text{year} \quad (13.16)$$

Value of water saved:

$$(22 - 8 \text{ gpm}) (60 \text{ min/hour}) (4 \text{ hour/day}) = 3360 \text{ gallons/day} = 12.7 \text{ kl/day} \quad (13.17)$$
$$(3360 \text{ gallons/day}) (\$.80/1000 \text{ gallons}) = \$2.69/\text{day} \quad (13.18)$$
$$\$2.69/\text{day} (250 \text{ day/year}) = \$672.50/\text{year} \quad (13.19)$$

Install thermostatically controlled valves to reduce the flow of cooling water
Many pieces of equipment in the food processing industry are water cooled, such as refrigeration compressor heads. Usually, the water flow is set high to make sure the equipment never overheats, even under maximum load. In one relatively large plant the combined flow of cooling water in the compressor room was estimated to be close to 37.8 l/min, (10 gallons/minute), or over 18.9 km^3 year (5 millions gallons/year). Seldom are the compressors operating constantly and they do not require cooling water when they are not operating. Thermostatically controlled valves limit cooling

water flow to maintain a steady pre-set temperature in the equipment being cooled. This usually results in at least a 50% water saving. Thermostatically controlled valves installed on compressors may have a payback as short as 3 months.

Recovering and upgrading animal by-products

Process changes, such as the examples given above, are specific for the equipment and processes listed. This section lists and discusses methods for recovering/upgrading animal by-products with associated energy conservation. It has been shown that protein recovered from by-products or even meat packing wastewater is often of a high quality and has good functional properties (Knorr, 1983; Perera and Anglemier, 1980).

The processes available to the animal-processing industry for upgrading or reclaiming by-products and conserving energy are listed in Table 13.14. The following text briefly describes each process. Some of the methods listed are discussed more fully in other parts of this book.

1. *Blood*

Blood is high in protein, minerals, and vitamins, making it a source of high-quality food (Resler, 1973). In the U.S., blood is not commonly used for human food; part of the blood from slaughtered animals is dried for use as other than human food (animal feed or fertilizer) and most of the rest is washed down the sewer and becomes a pollutant. Animal blood is used for food in other parts of the world. Processing of animal blood to fractionally remove protein and/or decolourize it may make the product more appealing.

Blood used for human consumption must be collected using USDA-approved methods to ensure cleanliness.

Chemical processing.

Tybor *et al.* (1973), Drepper and Drepper (1979) and Landmann and Dill (1972) describe procedures for manufacturing protein product from blood that is suitable for inclusion in food products. The stages involved in the procedure are collection, followed by addition of an anticoagulant, then centrifugation to separate the plasma and red cells. Plasma may be further treated (ultrafiltration is one method) and/or dried. Red cells are opened (haemolysis) and then treated with an enzyme (Drepper and Drepper, 1979) or other chemicals (Tybor *et al.*, 1973) for decolourization. The final decolourized product may be used directly in meat products or dried to a white powder.

Ultrafiltration/reverse osmosis.

Ultrafiltration (UF) and reverse osmosis (RO) are processes that separate and concentrate dissolved components from liquids. Small molecules, including water, pass through a semipermeable membrane under pressure, whereas protein and other 'large' molecules will be retained. A description of the process is given by Kaup (1973) and Fernando (1981). RO differs from UF in that the pore size for RO is much smaller thus retaining smaller molecules. Pressure for UF is in the range of 69–690 kPa (10–100 psi), while that for RO is in the range 3.4–10.3 MPa (500–1500 psi), though lower pressures are now being used.

Table 13.14 — Processing methods for animal product recovery/upgrading or energy conservation

Product	Processing methods	Application	Potential value
Blood	Chemical	Additive for processed meats. Balances the amino acids from vegetable proteins.	There are 110 000–180 000 metric tonnes (350–400 million lb) of beef blood solids in the blood removed from slaughter animals in U.S. per year (Resler, 1973; AMI, 1978). Blood of as high a quality from other animal species is not as readily available as beef blood because of difficulty of collecting without contamination.
	Ultrafiltration/ Reverse osmosis		
Bone	Mechanical deboning	Mechanically deboned meat (MDM) is used in a similar manner as trimmed meat. The quality is usually thought to be lower than that of hand-trimmed meat, mainly because of fine bone particles, texture and colour difference.	About 2 million metric tonnes (4.4 billions lb) of MDM could be recovered/year (Field, 1976). Pork carcasses could yield 1.4–1.8 kg (3–4 lb) more per carcass than with hand-trim (Goldstrand, 1975). There is a 50–70% yield of flesh from fish frames (Baker, 1980).
Protein	Mechanical boning and protein extraction	Can be incorporated into sausages to supply up to 20% of the protein content without objectionable flavour, texture, and odour.	Bone from freshly dressed animals contains more than 20% proteins and 15% fat (Katz and Ackroyd, 1976).
Viscera	Protein extraction	Protein extracted from viscera has good quality and functional properties for fabricated foods. (Perera and Anglemier, 1980; Young and Lawrie 1975)	Not enough data exist to accurately predict value. Protein can be extracted from viscera of animals.

Table 13.14 — (*continued*)

Product	Processing methods	Application	Potential value
Animal processing waste	Physical–chemical treatment	Treatment of animal-processing wastewater	Depends on the chemical analysis of the sludge, the rendering facilities at the plant and the constraints on sludge disposal. In one study of physical-chemical treatment of meat packing wastewater, 89% of the suspended solids were removed. The coagulated suspended solids contained 41% crude protein and 17% fat (Baugh, 1976).
	Biogas	Anaerobic treatment of animal-processing waste	Would depend on local energy costs, volume and type of waste treatment and disposal methods presently used.
	Production of single-cell protein	Meat packing waste	Depends upon consumer acceptance. Considerable market development would probably be required to utilize these products.
	Ultrafiltration for recovery of protein and to reduce BOD	Treatment of animal-processing wastewater to reduce BOD and total solids. Concentrate retained by the membrane can be dried into a nutritious animal food.	Not enough data exist to accurately predict value. In one trial, 94% of the total protein in wastewater sample was recoverable as animal feed (Shin and Kozink, 1980)
Trimmings, meat for curing	Tumbling or massaging	Binds trimmings, thus upgrading trimmings, which can be used for cured products.	Increases curing yield by 4–6% over that of non-tumbled tissue (Ockerman *et al.*, 1982a)
Liquid product	Concentration with multistage evaporation or reverse osmosis/ ultrafiltration. Reclamation of heat vapours from drying.	Used for concentrating solids in animal by-products	Potential exists for removing water from food products using less than 25% of the energy normally required by the evaporation process (Teixera, 1981).
Carcass	Maintain relative humidity close to 95% in coolers.	Meat coolers following kill floor.	Increases meat yield by 1% or more.

Source: Hansen and George (1983).

UF can be used to concentrate blood proteins without heat damage while salt and other small molecules are removed. UF can be used to prepare blood serum for use in sausage or to economically concentrate serum before it is spray-dried. RO can also be used to concentrate blood with greater retention of protein and minerals as compared with UF. Processing of blood with RO has not been popular in the U.S., probably because of critical membrane limitations (low temperatures, ease of fouling, etc.) and relatively inexpensive energy. Advancements have been made in membrane technology to give RO much wider application (SRI, 1981).

Bone

Mechanical deboning

Mechanical deboning is accomplished by pressing a ground or crushed meat/bone mixture against a porous metal screen with a screw press or piston. Soft tissue is forced through the openings, while bone is retained. A discussion of the process and the properties of mechanically deboned meat (MDM) — now referred to for labelling purposes as 'mechanically separated (species)' is found in Field (1976), Baker (1980), Goldstrand (1975), Katz and Ackroyd (1976), and Ockerman *et al.* (1981).

At present, hand-trimmed bones are treated as a by-product of little value. Bones constitute 16–20% of the carcass weight, and at least 30% of the bone weight can be saved as human food (Katz and Ackroyd, 1976; Field, 1976). Bones that are hard to hand-trim, such as the vertical column and ribs, yield the most meat. However, MDM is seldom used in amounts which exceed 30% of the product because colour, texture and flavour problems often occur when higher levels are used. More than 10% MDM in sausage may cause colour changes (Field, 1976).

Protein extraction

Bone protein extracts can be obtained from ground bones by an alkaline treatment and tumbling (ground bones are placed in rotating drum), short-term storage, filtration, precipitation, and centrifugation (Ockerman and Caldironi, 1982; Jelen *et al.* 1978). Ockerman and Caldironi reported that sausage made with up to 20% bone protein extract had good functional properties and was acceptable in flavour, texture, odour, and colour; the extract contained nearly 10% protein (wet basis).

Viscera

Gault and Lawrie (1980) describe a procedure for extracting protein from offal. Offal is homogenized in water, the pH is adjusted and a detergent solution may be added to the solution and agitated for 3 hours at room temperature. The protein is separated out by centrifugation. Perera and Anglemier (1980) report that about 90% of rumen protein could be extracted at pH 3 or 10 when the tissue was well homogenized. The rumen protein was about 30% lower in emulsifying capacity than that of skeletal muscle protein. The whippability and foam stability were superior to those of purified egg albumin and the protein had excellent solubility and consistency.

Meat-packing wastewater

Wastewater from animal processing is often difficult to treat, yet the major pollutants in the wastewater are of high nutritional value. Producing a saleable by-product from wastewater would help to offset the operating costs for wastewater treatment.

Single cell protein

Microorganisms that can be used to produce single-cell protein (SCP) include yeast, filamentous fungi, bacteria, and algae (Hang, 1979). These microoganisms can utilize a great variety of carbonaceous materials. Microorganisms feed on waste materials and build protein through cell synthesis. SCP provided by microorganisms may show an appreciable improvement in amino acid composition and quantity over the material they feed on (MWPS, 1975).

SCP production processes are capital and energy-intensive, and it may be necessary to nutritionally supplement the feedstock for the microorganisms (Litchfield, 1977). An advantage of SCP production in meat packing is that it may be possible to combine the process with waste treatment. More research will have to be done to determine the applicability of SCP for the meat industry.

Physical-chemical

The recovery of by-product from meat packing wastewater is generally an extra benefit of treating the wastewater. The cost of waste treatment may be reduced by sale of by-product recovered. Protein may be separated by coagulation and settling. Fats and oils may be seperated by flotation in a process such as dissolved-air flotation or electrocoagulation and can be skimmed off the surface (Clemens, 1981). Sherman (1979) reports on a process for specific precipitation of protein using lignin sulphonates under acid conditions. Chitosan, a by-product of shrimp and crab wastes, has been shown to be effective in reducing BOD and SS from meat- and poultry-processing wastes. Coagulated solids contained up to 68% protein on a dry-weight basis (Baugh, 1976).

Biogas

Volatile suspended solids in meat packing wastewater are often decomposed in anaerobic lagoons located at meat packing plants (Hansen, 1980). Biogas (methane) is produced as a by-product of this process. Meat packing plants may consider anaerobic digestion processes that are designed for collection and utilization of methane. Jewell (1979) describes methods of methane generation and collection.

Ultrafiltration

The permeate from ultrafiltration treatment of animal-processing wastewater may be discharged to the sewer without additional treatment or surcharges for high BOD and suspended solids. The retentate may contain significant amounts of protein and fat which can be dried for animal food. This process has been shown to work on a laboratory scale in a poultry-processing plant (Shin and Kozink, 1980).

Tumbling or massaging

Tumbling refers to placing the meat in a rotating drum that is shaped somewhat like a cement mixer. Massaging involves placing the meat into a vat in which a large rotating paddle performs the mechanical manipulation process. Tumbling or massaging of meat (Ockerman *et al*, 1982a) is an innovation in the meat-curing area. In the tumbling process, protein is extracted to form a binding agent. It can transform trimmings into a product that resembles intact cuts of meat, thus upgrading the trimmings. It also salvages protein that would otherwise be lost (exuded from the tissue by the brine) using conventional cure methods.

Liquid product

Many plants in the meat industry boil off liquid, with little or no reclamation of heat energy in the vapours. The hot vapours may even end up as an undesirable heat or odour pollutant. The drying process is best done in two stages: liquid concentration followed by drying. Concentration processes are discussed below (Flink, 1977).

Evaporation processes that conserve energy reclaim the heat of vaporization of water (about 2.26 MJ/kg (970.3 Btu/lb)) at 100°C (212°F). These processes include multiple-effect evaporators, mechanical vapour recompression (MVR), and batch cookers that utilize vapours to pre-heat incoming feedstock in a heat exchanger (Schwartzberg, 1977; Gartlan, 1975). The vapour generated in one effect of a multiple-effect evaporator is used to provide the heat required to produce evaporation downstream in an effect operated at lower pressure. In MVR, vapour from the liquid being concentrated is compressed to provide, through heat of compression, heat for further concentration of the liquid. In both cases, the heat of vaporization is reclaimed. Multiple-effect evaporators can be used in rendering (Anderson International 1983). A steam saving of 31% is reported by a rendering plant in Europe that uses reclaimed vapours from batch cookers to pre-heat raw feedstock going to an evaporator (Anon., 1981).

RO and UF can also be used to concentrate liquid food. Since no phase change is involved, the energy required to remove water by RO and UF is in the form of work to drive pressurizing and circulating pumps. Energy used in RO is related to pressure required to overcome osmotic forces. As the concentration of the solution increases, osmotic forces build, and system pressure must exceed osmotic forces. Because of this limitation, solution concentrations are limited. For pure sucrose, the limit is about 25% (Teixeira, 1981).

7. *Precision control of relative humidity in carcass coolers*

Coolers should be kept at 95% relative humidity (RH) to avoid shrink and condensation of water vapour on rails and structural members (Anderson, 1982). Beaded condensate in coolers is prohibited by government regulation for sanitary reasons. Controlling RH requires precise control of temperature, air movement, and moisture removal. A 0.6°C (1°F) spread between wet and dry bulb temperature at 2°C (35°F) gives a difference in RH of 10%. Air movement in the coolers is needed to achieve a uniform RH and temperature throughout the cooler.

Excess moisture will condense on the evaporator coils and be removed from the air. Anderson (1982) suggests running the coils wet (above freezing) to better control heat transfer rate and to avoid running a defrost cycle. Refrigeration units may run more efficiently with wet evaporator coils.

Hot deboning

Hot deboning is often paired with carcass skinning, used by many whole-hog processors and sausage makers. A discussion of the process is given by Ockerman *et al.* (1982b). Release of the muscle prior to rigor results in muscle contraction and some muscle toughening. Therefore, hot boning is usually used with tissue that will be ground or emulsified. Ockerman (1980) reported that 30–40% less time is required to bone a carcass hot; yet employees who are used to cold boning may initially object to changing. Advantages of the process include less shrinkage, less rancidity, increased shelf life, and better colour.

If used collectively, the processes discussed for recovering/upgrading animal by-products could substantially increase meat yield from animals and reduce energy consumption. Unfortunately, many of the processes described are not available on a commercial scale. Commercial development of some processes requires applications research and development of marketing strategy. These processes do indicate the potential for increased profit and pollution reduction by better utiliziation of all parts of the animal.

SUMMARY

Some animal parts are underutilized and significant amounts of blood and scraps are lost to the sewer. Additionally, many processing techniques use more water and energy than is needed to accomplish the given task. Supervisory personnel should develop a strategy to reduce pollution and increase profits. The plant must first be surveyed for pollution-reduction opportunities. Plants must develop a 'waste consciousness' including good housekeeping practices and watching for opportunities to reduce pollution. Processing methods must be constantly updated according to the state-of-the-art. Processes that need updating are identified by pollution and energy usage monitoring and consultation with key employees and outside consultants if necessary. A collection of processes that recover/upgrade animal by-products thereby reducing pollution and increasing profit are available.

APPENDIX: EXAMPLE PROBLEM FOR LAND APPLICATION OF ANIMAL-PROCESSING WASTE

Animal-processing waste is applied to land to be planted with corn.

Table 13.15 — Nutrient analysis of animal-processing waste

Parameter	Analysis	kg/10 000 l	(lb/1000 gallons)
Total Solids	6.58% wb[a]		
Total N		26.8	22.4
Ammonia N		13.9	11.6
Organic N		12.9	10.8
Phosphorus		4.4[b]	3.7
		10.2 kg P_2O_5	8.5 lb P_2O_5
Potassium		18.2[c]	15.2
		21.9 kg K_2O	18.3 lb K_2O
Calcium		8.5	7.1
Magnesium		2.9	2.4
pH	7.5		

[a]wb is wet basis.
[b]4.4 kg/10 000 l waste of the element phosphorus, however P is often reported as P_2O_5.
[c]18.2 kg/10 000 l waste of the element potassium, however K is often reported as K_2O.

Animal-processing waste application plan

Assume cropping needs are 224 kg available N/ha (200 lb/acre).

(a) Determine mineralized N available from previous years of animal-processing waste application: (Assume 100 000 l/ha (10 700 gallons/acre) yearly for previous four years). Assume half the organic nitrogen was available to plants the year it was spread. Organic N released during the second, third, fourth and fifth cropping years was 50%, 25%, 12.5% and 12.5% respectively of that released during the first cropping season.

64.5 kg N/ha=[0.5 (12.9 kg N/10 000 l)×100 000 l/ha] (0.5+0.25+0.125+0.125)
57.8 lb N/acre=[0.5 (10.8 lb N/1000 gallons)×10 700 gallons/acre] (0.5+0.25+0.125+0.125)

(b) Determine N available in animal-processing waste during year of application. Assume 50% loss of ammonia nitrogen (NH_3 N) due to volatilization.

13.4 kg N/10 000 l=0.5 (12.9 kg organic N+13.9 kg NH_3–N)/10 000 l
11.2 lb N/1000 gallons=0.5 (10.8 lb organic N+11/6 lb NH_3–N)/1000 gallons

(c) Determine how much animal processing waste will be required to meet all the 224 kg/ha (200 lb/acre) nitrogen needs with animal processing waste. (Amount of N needed is found in Table 13.6). N needed this year is amount required by crop minus amount available in mineralized form from previous years.

159.5 kg N/ha needed this year=224 kg N/ha needed − 64.5 kg N/ha from past years.

$$119 \text{ kl waste/ha} = \frac{159\text{kg N/ha needed}}{13.4 \text{ kg N}/10\,000 \text{ l} \times 10\,000}$$

142.2 lbs N/acre needed = 200 lb N/acre − 57.8 lb N/acre from past years

$$12\,700 \text{ gallons waste/acre} = \frac{142.2 \text{ lb N/acre}}{11.2 \text{ lb N}/1000 \text{ gallons} \times 1000}$$

(d) If applying 119 kl (12 700 gallons) animal-processing waste/ha, how much P & K is applied?

52.4 kg P = 11.9 × 4.4 kg P or 121.4 kg P_2O_5
216.6 kg K = 11.9 × 18.2 kg K or 260.6 kg K_2O
46.6 lb P = 12.7 × 3.7 lb P or 108 lb K_2O
193 lb K = 12.7 × 15.2 lb K or 232.4 lb K_2O

(e) Assume you want to fully utilize the P & K nutrients in this animal processing waste. Your soil tests very low for P & K. How much land planted with corn (yield goal 17.4 m^3/ha (200 bushels/acre) can you fertilize with 119 kl (5280 gallons) of animal-processing waste: (a) according to P requirements. (b) according to K requirements. P_2O_5 and K_2O needs are found in Table 13.8.

(a) $$1.4 \text{ ha} = \frac{121.4 \text{ kg } P_2O_5}{84 \text{ kg } P_2O_5/\text{ha}}$$

$$1.4 \text{ acre} = \frac{108 \text{ lb } P_2O_5}{75 \text{ lb } P_2O_5/\text{acre}}$$

(b) $$4.2 \text{ ha} = \frac{260.6 \text{ kg } K_2O}{62.6 \text{ kg } K_2O/\text{ha}}$$

$$4.2 \text{ acre} = \frac{232.4 \text{ lb } K_2O}{55 \text{ lb } K_2O/\text{acre}}$$

Therefore if N requirements are met, P & K requirements are exceeded by 1.4 and 4.2 times respectively. One could apply animal processing waste to meet P or K needs and supply additional N required with commercial fertilizer.

REFERENCES

AMI (1978) *Meat Facts*. American Meat Institute, Washington DC.

Anderson International (1983). Private communication 6200 Harvard Ave., Cleveland, Ohio, A.I.C.

Anderson, R. W. (1982). How to eliminate condensate and save energy in meat and poultry plants. *ASHRAE J.* Aug. p 30.

Anon. (1981). State-of-the-art rendering in Holland. *Meat Proc.* **20**(6) 18.

Baker, D. A., Wigmore, A. H. and White, J. E. (1974). *Treatment of packing house wastes by araerobic lagoons and plastic media filters*. U.S. EPA-660/2-74-027, Washington DC, U.S. Environmental Protection Agency.

Baker, R. C. (1980). Edible recoverables-minced fish, etc. In *Proceedings of a Conference on Seafood Waste Management of the* 1980's, p. 226, W. S. Otwell (ed.), Orlando, FL, Sept. 23–25.

Baugh, W. A. (1976). Chitosan — a polymer from seafood waste for use in treatment of food processing wastes and activated sludge. *Proc. Biochem.* **11** 13.

Berthouex, P. M., Grothman, D. L., Dencker, D. O. and Scully, L. J. P. (1977). *Characterization and in-plant reduction of wastewater from hog slaughtering operations*. U.S. EPA-660/2-77-097. Washington DC, U.S. EPA.

Brasington, C. F. (1978). *Utility usage in small slaughter plants. ARS-S*-174, *Agricultural Research Service, USDA*. College Station, Texas.

Callander, I. J. and Barford, J. P. (1983). Recent advances in anaerobic digestion technology. *Proc. Biochem.* **18** (4), 24.

Clemens, O. A. (1981). Electrocoagulation solves packinghouse problems. *Ind. Wastes* **27**(1) 20.

Cheremisinoff, P. N. (1987). Biotechnology treating industrial/municipal wastes and wastewater. *Pollution Engr.* **11**(9) 74.

Chynoweth, D. P., Fannin, K. F., Jerger, D. E., Srivastava, V. J., Biljetina, R. (1984). *Anaerobic digestion of biomass: status summary and R & D needs*/1983 *Topical Report*. Institute of Gas Technology IIT Center. Chicago.

Day, D. L. and Sweeten, J. M. (1979). Manure refeeding: regulations and equipment needs. *Ag. Engr.* **60,** 26.

Drepper, G. and Drepper, L. (1979). Verfohren zur Herstellung neuer Eiwei Bprodukte aus Schlachttierblut fur Nahrungsmittel. *Fleischwirtsch* **59**(9) 1252.

EPA (1974). *Red meat processing*. Segment of the meat product and rendering processing point source category. U.S. EPA-440/1-74-012-9. Washington DC, U.S. Environmental Protection Agency.

Fernando, T. (1981). Concentration of animal blood by ultrafiltration. *Biotech. and Bioengr.* **23** 19.

Field, R. A. (1976). Increased animal production with mechanical deboners. *World Rev. An. Prod.* **12** 6.

Flink, J. M. (1977). Energy analysis in dehydration processes. *Food Technol* **31**(3) 77.

FWPCA, (1967). *The cost of clean water*, Vol III, Industrial Profile No. 8, Meat Products. Washington DC, US Department of the Interior, Federal Water Pollution Control Administration (FWPCA Pub. No. I.W.P.-8).

Gartlan, A. F. (1975). Energy conservation and its relation to material handling in the food industry. In *Proceedings of 15th Annual Short Course for the Food Industry*. Institute of Food and Agricultural Science, University of Florida Gainesville.

Gault, N. F. S. and Lawrie, R. A. (1980). Efficiency of protein extraction and recovery from meat industry by-products. *Meat Sci.* **4** 167.

Goldstrand, R. E. (1975). Mechanical deboned meats, yields and product characteristics. In: *Proceeding, Reciprocal Meat Conference*, p. 116, University of Missouri Columbia.

Hang, Y. D. (1979). Production of single-cell protein from food processing wastes. In: *Food Processing Waste Management*, J. H. Green and A. Kramer (eds.), p. 442. Westport, Connecticut, AVI.

Hansen, C. L. (1983). Methods for animal waste recovery and energy utilization. *Food Tech.* **37**(2) 77.

Hansen, C. L. (1980). Optimization of water usage, wastewater management, and associated energy usage in a meat packing plant. Ph.D. Thesis, The Ohio State University, Columbus.

Hansen, C. L., Fields, E. L. and Huff, R. C. (1983). *Energy conservation in small meat, poultry & dairy processing plants*. Paper 83–6002, American Society of Agricultural Engineers. St Joseph, Michigan.

Hansen, C. L., White, R. K. and Okos, M. R. (1984). Optimization of water management and associated energy in a meat packing plant. *Trans. of the ASAE*. **27** 305–310.

Hansen, C. L. and George, V. I. (1983). Recovering/upgrading animal byproducts with associated energy conservation. Paper 83–6543, St. Joseph, Michigan, American Society of Agricultural Engineering.

Jelen, P., Richard, S., Earle Oldfield, M., Edwardson, W. and Hamilton, R. G. (1978). Low temperature extraction of bones for protein recovery. *Food Tech. in N. Zealand*, Aug. p 3.

Jewell, W. J. (1979). Future trends in digester design. Presented at 1st International Symposium on Anaerobic Digestion, University Industrial Centre, University College, Cardiff, Wales.

Kaup, E. C. (1973). Design factors in reverse osmosis. *Chem. Eng.* **80** (April 2) 46.

Katz, M. and Ackroyd, H. (1976). Separating meat from bone. Reprint from Meat Mag., April.

Knorr, D. (1983). Recovery of functional proteins from food processing wastes. *Food Tech.* **37**(2) 71.

Landmann. W. A. and Dill, C. W. (1972). *Blood protein recovery research*. College Station, Analytical Science Department Texas A & M University.

Litchfield, J. H. (1977). Single-cell proteins. *Food Tech.* **31**(5) 175.

Loehr, R. C., Jewell, W. J., Novak, J. D., Clarkson, W. W., Freidman, G. S. (1979a). *Land application of wastes vol.* 1. Van Nostrand Reinhold, New York.

Loehr, R. C., Jewell, W. J., Novak, J. D., Clarkson, W. W., Friedman, G. S. (1979b). *Land application of wastes vol.* 2. Van Nostrand Reinhold, New York.

MWPS. (1985). *Livestock waste facilities handbook*, (MWPS-18) second edn., Ames, Iowa, Midwest Plan Service.

MWPS. (1975). Livestock waste management with pollution control. MWPS-19. Ames, Iowa, Midwest Plan Service.

Ockerman, H. W. (1980). *Review of current status of hot boning in the United States.* Presented at Simposio Nacional de Ciencia y Technologia de Carnes, Buenos Aires, Nov. 2–5.

Ockerman, H. W. and Caldironi, H. A. (1982). Incorporation of bone protein extracts into cooked sausage. Unpublished proceedings, 28th European Meeting of Meat Research Workers. Madrid, Spain, Sept. 5–10.

Ockerman, H. W., Houber, J.H., Kral, B., Plimpton, R. F. and Schad, M. (1981). Effect of bone source and storage on the role of mechanically deboned pork in rancidity development in a cooked and smoked sausage. *J. Fd. Sci.* **46** 220.

Ockerman, H. W., Plimpton, R. F., Cahill, V. R., Parrett, N. A. and Van Staven, B. (1982a). Meat tumbling or massaging. Columbus, Department of Analytical Science. The Ohio State University and Ohio Agricultural Research & Development Center.

Ockerman, H. W., Cahill, V. R., Plimpton, R. F. and Parrett, N. A. (1982b). Extension of shelf life on meat products. Columbus, Department of Analytical Science, The Ohio State University and Ohio Agricultural Research & Development Center.

Perera, C. O. and Anglemier, A. F. (1980). Utilization of slaughter plant waste proteins: an investigation of the nature and some functional properties of bovine rumen tissue proteins. *J. Food Science* **45** 617.

Pilney, J. P., Erickson, E. E. and Halvorson, H. O. (1972). Results of industrial waste study. *Nat. Prov.* **166** (8) 27.

Reddell, D.L., Brown, K. R. and Sweeten, J. M. (1976). *Land disposal of blood and paunch manure.* Presented at Seminar on Management of Slaughterhouse and Meat Processing Wastes. Texas Agricultural Extension Service. Waco, Texas, July.

Reed, S. C., Crites, R. W. (1984). *Handbook of land treatment systems for industrial and municipal wastes.* Noyes Publications, Park Ridge, New Jersey.

Resler, M.A. (1973). Diverting slaughter animal blood into human food supply channels. Master's Thesis. Utah State University, Logan.

Schwartzberg, H. G. (1977) Energy requirements for liquid food concentration. *Food Tech.* **31** (3) 67.

Sherman, R. J. (1979) Pretreatment of proteinaceous food processing wastewaters with lignin sulfonates. *Food Tech.* **33** (6) 50.

Shin, J. C. H. and Kozink, M. B. (1980). Ultrafiltration treatment of poultry processing wastewater and recovery of a nutritional by-product. *Poultry Sci.* **59** 247.

SRI (1981). *Reverse osmosis*. Guideline 1061, International Business Intelligence Program, Stanford Research Institute, Menlo Park, California.

Steffen, A. J., Lindenmeyer, D., Ginaven, M. E., Johnson, R., Grimes, C., Nord, R. and Micdaner, W. H. (1973) In: Process Modifications and Pretreatment, Upgrading Meat Packing Facilities to Reduce Pollution, EPA Technology Transfer Seminar Publication. Cincinnati, Ohio, U.S. Environmental Protection Agency.

Stevens, R. M., Elazar, D. J., Schlesinger, J., Lockard, J. F. and Stevens, B. A. (1972) *Green land — Clean streams*. Center for the Study of Federalism, Temple University Philadelphia, PA.

Sweeten, J. M. (1978) *Pollution control requirements for meat processors*, Bull. No. MP 1371. Texas Agricultural Extension Service.

Teixeira, A. A. (1981) *Reverse osmosis and mechanical vapor-recompression in cane and beet sugar processing*. Paper 81–6022, American Society of Agricultural Engineers, St. Joseph, Michigan.

Tybor, P. T., Dill, C. W. and Landmann, W. A. (1973). Effect of decolorization and lactose incorporation on the emulsification capacity of spray-dried blood protein concentrate. *J. Food Sci.* **38** 4.

U. S. Environmental Protection Agency (1974). *Development document for effluent limitations guidelines and new source performance standards for the red meat processing segment of the meat product and rendering processing, point source category*. EPA–440/1-74-012-a. Washington, DC, USEPA.

Walker, L. P. (1980) *Energy production and conservation on a dairy farm*. Paper 80–3003, St. Joseph, Michigan, American Society of Agricultural Engineers.

White, R. K. and Logan, T. J. (1981) *Land application of manure and wastewater (Part II), Optimum utilization of manure nutrients*. AEX 705, Ohio Cooperative Extension Service. The Ohio State University. Columbus.

Witherow, J. L. (1973). *Small meat packers wastes treatment systems*. Presented at 4th National Symposium on Food Processing Wastes, Syracuse, N.Y. March 26–28.

Witherow, S. C., Yin, S. C. and Farmer, D. M. (1973) *National meat packing waste management research and development program*. EPA-R2-73-178, U.S. Environmental Protection Agency, Corvallis, Oregon.

Young, R. H. and Lawrie, R. A. (1975). Utilization of edible protein from meat industry by-products and waste. *J. Food Tech.* **10** 453.

Zall, R. R. (1979) Whey treatment and utilization. In *Food processing waste treatment*, J. H. Green and A. Kramer (eds.), p. 175. AVI, Westport, Connecticut.

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Animal By-Product Processing

ELLIS HORWOOD

This handbook reports methods of animal by-product processing and highlights recent innovations in the field with respect to energy conservation, product upgrading, and waste reduction, utilization, and disposal. It provides information on quantities of by-products available, their chemical and histological properties, on alternative processing techniques, associated equipment and energy requirements. By-products from the meat, poultry, and sea-food processing industries are covered. In their discussion of processing techniques, the authors include equipment, energy, water, labor, and chemicals needed. Numerous tables, illustrations as well as comprehensive reference lists help the reader to get easy access to the information needed by people working in the field.

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